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ANTHROPOMETRIC RELATIONSHIPS OF BODY AND BODY SEGMENT MOMENTS OF INERTIA

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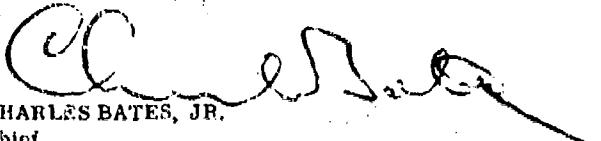
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This report documents the results of a study aimed at demonstrating that mass distribution properties of the human body and its segments can be predicted from anthropometric dimensions. Investigators combined stereophotometric and anthropometric techniques to measure 31 male subjects. Bodies were photographically segmented into 24 parts and their volume, centers of volume and principal moments of inertia established stereometrically. Principal moments were measured about three principal axes of inertia which

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were established with reference to anatomical axis systems based on easily located body landmarks.

Seventy-five body size variables were measured anthropometrically and an additional 10 dimensions were derived from the measured variables. Multiple regression equations were devised for the total body and for each segment using the most highly correlated variables on each segment, and stature and weight for determining volume and principal moments of inertia.

Included is a brief review of the literature with emphasis on earlier studies by authors which provide the rationale for the reliability of the stereophotometric method in determining mass distribution properties of living subjects. The data analysis section provides tables illustrating each of the segments and their axis systems, the segmental data established in this study, and a series of regression equations estimating volume and principal moments from anthropometric measurements.

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PREFACE

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The intent of this research was to establish the relationship between human body size and its mass distribution properties. Stereophotometric and anthropometric techniques were combined to measure a group of 31 living male subjects with the object of arriving at a means of estimating volume and moments of inertia of the body and its parts from anthropometric dimensions. Numerous anthropometric measurements were taken and various combinations of dimensions were used in predictive equations to obtain those variables which provided the best estimates of the mass distribution characteristics which had been stereophotometrically determined.

In our previous two studies of the mass distribution properties of man (Clauser et al., 1969; Chandler et al., 1975), all subject specimens were cadavers. This work provided interim data until such time as we could develop methods and procedures for making similar assessments on the living. In the second of these studies, a double blind investigation was designed, in which stereophotometric assessments of mass distribution were made and compared to measurements empirically determined. An evaluation of results indicated that an acceptable level of correspondence existed between the two measurement techniques. This indicated that the stereophotometric method could be used to obtain estimates of mass distribution parameters from living subjects and provided us with a means for testing and validating the hypothesis that moments of inertia of separate parts of the body might be predicted from relevant dimensions of these parts.

This study demonstrates that body size and moments of inertia are related and the correlations can be used to develop regression equations for predicting mass distribution characteristics. The establishment of reliable predictive equations suggests that more difficult, expensive and time-consuming empirical measurements and modeling calculations can be eliminated. Further, if anthropometry can be used to estimate mass distribution properties, then, for the first time, large-scale population data could be obtained for those groups for whom sufficient anthropometry is available.

Chapter I

HISTORICAL PERSPECTIVES

Despite the attention of investigators over the past 200 years, the problem of accurately measuring the mass distribution properties of the human body remains almost as knotty today as it did in 1679 when the earliest recorded work described a scheme for ascertaining the center of mass of nude men by stretching them on a platform balanced on a knife edge (Borelli, 1679). While weight, volume, center of mass and moments of inertia of the whole body can be measured in a number of ingenious ways on living human beings, comparable information for segments of the body can be empirically measured only on cadavers. The expense and difficulties of research involving the use of cadavers and their dissection into component parts and the complexity involved in the design and development of the measuring apparatus have severely limited these investigations to small sample sizes from which data cannot be safely universalized. Additionally, cadavers do not approximate living persons of the same size. Research has demonstrated that supine and standing height differ and that cadavers lose weight progressively after death (probably through loss of body fluids). While sufficient fluid can be injected into a cadaver to simulate "normal" appearance, increases in various circumferential measurements are so variable as to make this method quite unsatisfactory in predicting living body size accurately (Todd and Lindala, 1928).

Live subjects were used by Weber and Weber (1836) to determine the center of mass by moving a body on a platform until it balanced and then reversing the body and repeating the procedure. The mean position between the two balance points was a more accurate approximation of center of mass than that obtained from Borelli's single measurement technique.

Some 25 years later Harless (1860) extended the Webers' experiments to studies of center of mass on body segments with a view to determining the center of mass along the long axis of as many movable body parts as possible. Harless cut the bodies of two cadavers into 18 parts. The volume of each segment was calculated from the mass using a postulated specific gravity of 1.066. Harless later provided further verification of his findings when he weighed 44 segment extremities from seven male and female corpses first in air and then in water. From these data he concluded that sex and age were significant factors in the variability of the specific gravity of segments of the human body.

While the list of investigations in this field is very long, perhaps the best known and most often cited are the studies of Braune and Fischer (1889 and 1892), Dempster (1955), Clauser et al. (1969), and Chandler et al. (1975).

Although sample sizes have of necessity been small, various researchers have undertaken the development of equations with a view toward applying known cadaver data to living bodies. Barter (1957), using data from Braune and Fischer, and from Dempster, prepared a series of equations for predicting segment weights from body weight. These have been used extensively by designers and engineers, despite limitations clearly specified by Barter.

In 1969 Clauser et al. determined weight, volume and center of mass on 14 body segments from each of 13 cadavers. They developed a series of multi-step regression equations aimed at predicting segment variables from anthropometric dimensions. Weight of the trunk segment, for example, was found to be best predicted by weight, trunk length and chest circumference measurements obtained from the whole body.

If the static mass distribution variables of the human body have presented tangled problems, its dynamic properties have formed a massive Gordian knot which investigators have not yet cut. As long ago as 1892, Braune and Fischer enlarged on earlier studies to include investigation of moments of inertia as well as volume, mass and center of mass. Using two adult male cadavers, they measured moments of inertia about the longitudinal axis and one axis perpendicular to the longitudinal axis of 11 segments. Dempster expanded these experiments still further by using segments from eight cadavers, and measuring moments of inertia about two parallel transverse axes. Others (notably, Santschi et al., 1963 and Ignazi et al., 1972, using live subjects; Liu and Wickstrom, 1973, using a torso segment), measured moments of inertia about as many as three axes. None of these investigators, however, found the principal axes of inertia from which principal moments of inertia are determined, although it has often been mistakenly assumed that results of one or more of these studies did provide these basic data.

The inertia tensor of a rigid body may be determined relative to any origin and any coordinate system orientation. Since there is an infinite number of such choices, there is an infinite number of possible inertia tensors for a given body. However, for a given origin, a unique inertia tensor exists for a non-symmetric body, which represented in matrix form has only nonzero diagonal elements. These elements are the principal moments of inertia of the body, and for each of these there is a corresponding principal axis of rotation. These principal axes form an orthogonal set, and are aligned with the axes of the coordinate system in which the inertia tensor is in diagonal form.

Observation of the general symmetry of a body may provide some insight into the approximate orientation of the principal axes. However, the actual determination of principal axes must be carried out analytically - generally using measured products and moments of inertia. These were measured for the first time by Chandler et al. in 1975 using the intact bodies and, subsequently, 14 dismembered segments of six adult male cadavers. The measured moments of inertia of the intact specimens were compared to findings from five live subjects of comparable weight and stature measured in an earlier study (Santschi et al., 1963) and a satisfactory level of agreement was found. Nevertheless, as the authors of the Chandler study pointed out, investigators were still not much closer to establishing population estimates for inertial properties.

The search for more widely applicable means of measuring mass distribution properties had also been pursued for many years by investigators attempting a more simplified approach to the problem. Long before the widespread use of high-speed computers, researchers were drawn to the possibilities of analytical and geometric modeling and approximating.

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Harless (1860) verified the use of various geometrical forms as analogues of human body parts by comparing their volume and center of mass measurements with those obtained on body segments of a cadaver. Von Meyer (1863, 1873) studied the movement of center of mass in the body with changes in its positions by reducing the head, torso and appendages to elemental ellipsoids and spheres.

Modern day research by investigators such as Clauser, reported by Simons and Gardner (1960), Whitsett (1962), Hanavan (1964), Wooley (1972), and Bartz and Gianotti (1973), to name but a few, has been aimed at the development of mathematical man models, chiefly for use in astronaut maneuvering simulation and in auto-crash research. Three-dimensional models, based on anthropometric data, have also been developed.

While mathematical modeling, through decades of trial and error and modification of geometric shapes, has produced reasonably usable analogues, its limitations are apparent. Both two- and three-dimensional models now in use are statistical representations of 5th, 50th and 95th percentile "persons" and, as such, do not accurately represent the body proportions of actual people since percentiles are not additive and it is impossible to assemble models from percentile values without manipulating some body part or parts (McConville and Churchill, 1976; Robinette and Churchill, 1979). Furthermore, even in mathematical modeling, verification of calculations on which mass distribution properties of segments are based can only be made from cadaver data.

Interest has focussed in the past decade on a sophisticated new technique which shows considerable promise as an accurate means of measuring mass distribution properties on living human beings and their segments. This technique, known variously as stereophotometrics, biostereometrics and photostereogrammetry, involves three-dimensional photography of the subject by cameras placed at strategic locations. The coordinates of a given number of points on the body serve as input to a digital computer which can then "recreate" the body or any of its photographed parts in all its geometric subtlety. This method, if proven accurate, would greatly refine the mathematical modeling procedures in current use since it can be used, for example, to measure and simulate the shape of an actual living head which is, after all, a good deal more irritatingly irregular than a sphere.

Stereophotometrics was first applied to a study of mass distribution by Dr. Robin Herron of the Biostereometrics Laboratory at the Texas Institute for Research and Rehabilitation (Herron et al., 1974). In that investigation periods of oscillation were measured and moments of inertia computed for three subjects riding a pendulum. Stereophotometric records were then made of the same subjects and their mass distribution properties calculated. The periods of oscillation were determined and a comparison with the measured periods revealed a close agreement.

Recognizing the possibilities of this method, Clauser saw the opportunity for a further test of its validity in conjunction with the Chandler et al. study (1975) of mass distribution on six cadavers and their segments. A double blind study ensued and preliminary results, reported by McConville and Clauser (1976), showed a high degree of correlation between findings

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obtained by the stereophotometric technique and those obtained by direct measurement of the cadaver segments, even to the extent of validating one suspected data point obtained through direct measurement.

In the study to be described here, investigators made further use of the stereophotometric technique to determine the relationship between the anthropometry of the body and its segments and mass distribution characteristics of living subjects.

Chapter II

STUDY DESIGN

This study was conducted in several phases and involved a considerable amount of planning and groundwork at several locations before the actual measurement of subjects began. The planning stage included the establishment of primary segments and planes of segmentation, selection of body-size dimensions to be measured and establishment of the anatomical axis systems for the body and its segments.

A pretest, using one subject, was designed and carried out to further develop and refine the techniques to be used and to further validate the stereophotometric assessment of human body moments of inertia. A reasonably representative sample was then selected.

In the test itself each subject was anthropometrically measured and marked with the landmarks to be used for photography. Stereophotometric photographs of each subject were then obtained.

Analytic procedures included: stereophotometric assessment of volume, principal moments and principal axes of inertia for the total body and its segments; preparation of a regression analysis of the anthropometry with the volume and moments of inertia; and analysis of the resulting data to determine whether body size measurements can accurately predict mass distribution parameters.

SEGMENTATION

The primary body segments used in this study were defined by using planes of segmentation similar to those used in our previous studies (Clauser et al., 1969; Chandler et al., 1975). The delineation of some additional segments was made possible because segmentation can be achieved more simply by photography than on cadavers. The segments defined were:

1.	Head	14.	Right Calf
2.	Neck	15.	Right Foot
3.	Thorax	16.	Left Flap
4.	Abdomen	17.	Left Thigh minus Flap
5.	Pelvis	18.	Left Calf
6.	Right Upper Arm	19.	Left Foot
7.	Right Forearm	20.	Right Forearm and Hand
8.	Right Hand	21.	Left Forearm and Hand
9.	Left Upper Arm	22.	Right Thigh
10.	Left Forearm	23.	Left Thigh
11.	Left Hand	24.	Torso
12.	Right Flap	25.	Total Body
13.	Right Thigh minus Flap		

Segments 20-25 are summations of previously tabulated individual segments.

The planes of segmentation,* illustrated in Figure 1, were identified and located in the following ways:

Head plane: passes through the left and right gonial points and nuchale.†

Neck plane: a compound plane in which a horizontal plane originates at cervicale and passes anteriorly parallel with the standing surface. A second plane originates at the lower of the two clavicale landmarks, rises 45° from the horizontal and passes diagonally superiorly-posteriorly until it intersects with the horizontal plane.

Thorax plane: originates at the 10th rib mid-spine landmark and passes through the torso parallel with the standing surface.

Abdominal plane: originates at the higher of the two ilio-cristale landmarks and passes through the torso parallel with the standing surface.

Hip plane: originates at the center of the crotch and passes laterally midway between the anterior superior iliac spine and the trochanteric landmarks along the lines of the right and left inguinal ligaments.

Thigh flap plane: originates at the gluteal furrow landmark and passes through the thigh parallel to the standing surface.

Knee plane: passes through the lateral femoral epicondyle landmark parallel to the standing surface.

Ankle plane: originates at the sphyrion landmark and passes through the ankle parallel to the standing surface.

Shoulder plane: originates at the acromion landmark and passes downward through the anterior and posterior scye creases at the level of the axilla.

Elbow plane: originates at the olecranon landmark and passes through the medial and lateral humeral epicondyle landmarks.

Wrist plane: originates at the ulnar and radial styloid landmark and passes through the wrist perpendicular to the long axis of the forearm.

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* All planes are described with reference to the body in the erect standing position.

† Definitions of all the body landmarks are given in Appendix A.

Figure 1.   Total body segmentation scheme.

A segmental axis system was established for the total body and for each of the 24 segments. These were right-hand orthogonal systems based on palpable, largely bony, landmarks and were used to provide a consistent reference for the principal axes systems independent of body segment position. The principal axes could then be located with respect to the anatomical axes, thus permitting duplication of measurements on other subject populations and comparison between subjects. This represents a major step forward from past investigations in which principal axes were located with reference to fixed points in the laboratory.

It should be noted that three landmarks are used to establish the original plane, two additional landmarks establish a plane perpendicular to the first, and a single additional landmark is used to establish a plane perpendicular to both. The origin of each axis system is the common point of intersection of the three planes with +Z being from the origin towards the head, +X being from the origin towards the front of the body and +Y being from the origin towards the left of the body.

The landmarks used to establish the axis system for each segment are as follows:

1. Head Axis: XY plane - right and left tragion and right infraorbitale

                  YZ plane - right and left tragion

                  XZ plane - sellion

2. Neck Axis: XZ plane - Adam's apple (midpoint of the anterior triangle at the level of the thyroid cartilage), cervicale and suprasternale

                  XY plane - one-half the distance between the right clavicale and cervicale and the left clavicale and cervicale

                  YZ plane - cervicale

3. Thorax Axis: XZ plane - suprasternale, cervicale and at mid-spine at level of 10th rib

                  YZ plane - cervicale and 10th rib level at mid-spine

                  XY plane - 10th rib level at mid-spine

4. Abdomen Axis: XY plane - right and left 10th rib and at mid-
                            spine at level of 10th rib

                   YZ plane - right and left 10th rib

                   XZ plane - 10th rib mid-spine

5. Pelvic Axis: YZ plane - right and left anterior superior
                            iliac spine and symphysion

                   XY plane - right and left anterior superior
                            iliac spine

                   XZ plane - mid-spine at level of posterior
                            superior iliac spine

6. Right Upper Arm: YZ plane - acromion and right and left
·9. Left Upper Arm   humeral epicondyles

                      XZ plane - lateral epicondyle and acromion

                      XY plane - acromion

7.   Right Forearm: YZ plane - distal end of the ulnar and
10. Left Forearm   radial styloid processes and
20. Right Forearm and Hand   radiale
21. Left Forearm and Hand
                           XZ plane - distal end of the ulnar styloid
                                      process and radiale

                           XY plane - radiale

8.   Right Hand: YZ plane - dactylion and the lateral aspect
11. Left Hand   of the metacarpal-phalangeal joint
                                   of digits II and V

                       XY plane - the lateral aspect of the metacarpal-
                                  phalangeal joint of digits II and V·

                       XZ plane - metacarpale III

12. Right Flap   YZ plane - trochanterion and right and left
13. Right Thigh minus Flap   lateral femoral epicondyles
16. Left Flap
17. Left Thigh minus Flap XZ plane - lateral femoral epicondyles
22. Right Thigh   and trochanterion
23. Left Thigh
                          XY plane - trochanterion

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14. **Right Calf:**   YZ plane - tibiale, sphyrion and the lateral malleolus
18. **Left Calf**

                  XZ plane - sphyrion and tibiale

                  XY plane - tibiale

15. **Right Foot:**   XY plane - metatarsal-phalangeal I and V landmarks
19. **Left Foot**   and the posterior calcaneus

                  XZ plane - tip of digit II and posterior calcaneus

                  YZ plane - metatarsal-phalangeal I landmark

Total Body: the same as pelvis

A PRELIMINARY TEST

In.a pretest designed to refine and further validate the techniques to
be used in the forthcoming study, investigators empirically established the
moments of inertia for one subject about two axes in the sitting position and
one axis in the supine position and compared these results with those obtained
from the stereophotometric assessment. The subject was seated in a special
specimen holder, which assured a fixed posture during the measurement of
moments. The seated-specimen holder with the subject restraint systems of
foam blocks and tape is illustrated in Figure 2.

Figure 2.   Subject seated and restrained in
specimen holder

After the subject was properly positioned in the specimen holder, the center of mass of the composite was located by suspension and the torsion pendulum specimen mounting plate affixed to the specimen holder at the center of mass. This procedure is illustrated in Figure 3 in which a manikin is shown in the specimen holder during a trial run.
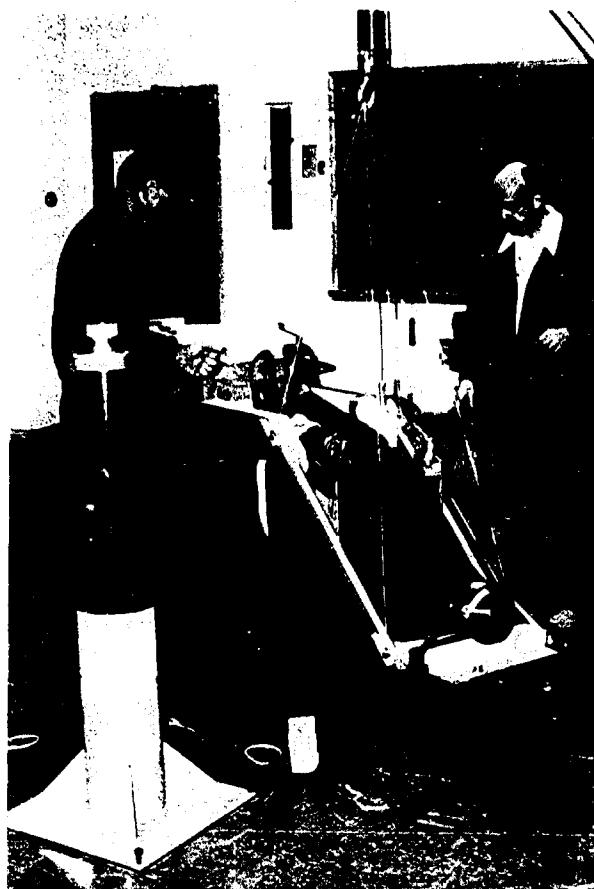
Figure 3.   Establishing the center of gravity
of the subject and specimen holder.

The composite (subject and holder) was then mounted on the torsion pendulum* and the periods of oscillation were measured (see Figure 4).   A minimum of 15 counts were made and averaged for each axis.   The subject was removed from the holder and the process repeated for the empty specimen holder.

The proposed surface dimensions were measured on the subject, targets were fixed to the body to indicate landmarks for segmentation and segment axis systems, and the stereophotographs were made.   This opportunity was taken to evaluate the various segmentation planes proposed for the study. The principal moments of inertia were then estimated by stereophotometric assessment (the method used is described below) and compared to those measured on the pendulum.   The results of this comparison are given in the table below.

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* Manufactured by Space Electronics, Inc., Model XR-250.
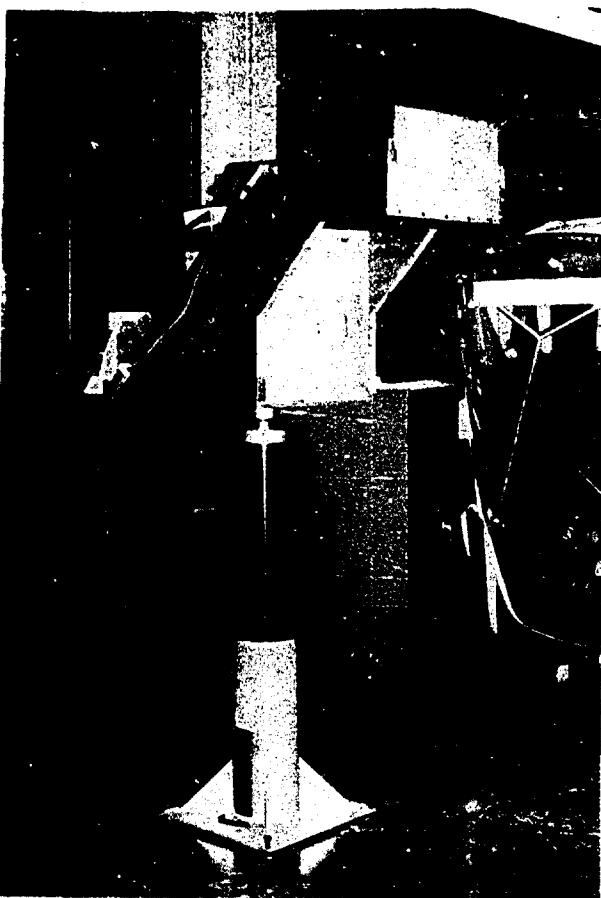
Figure 4. Subject and holder mounted on
torsion pendulum.

TABLE 1

COMPARISON OF MEASURED VALUES WITH STEREOPHOTOMETRICALLY
ESTIMATED VALUES FOR PRINCIPAL MOMENTS OF INERTIA
(in gm cm^2)

Position	Axis	Measured I_O	Stereo-photometric Estimated I_O	Δ	$\Delta\%$
Sitting	Z	38,299,252	33,333,924	4,965,328	-12.96%
Sitting	Y	77,192,067	74,068,259	3,123,808	- 4.05%
Supine	X	182,934,444	180,956,256	1,978,188	- 1.08%

The disagreement between the two measures ranged from a low of approximately one percent for the supine X axis to a high of approximately 13 percent for the sitting Z axis. The latter has the smaller moment of inertia, is a posture which is most difficult to define analytically in terms of segment orientation, and as a result is subject to the largest relative error in terms

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of both its empirical determination as well as its stereophotometric estimation. From this evaluation we concluded that the degree of correspondence of the stereophotometrically estimated moments were sufficiently high with those empirically determined to pursue the planned investigation. This was believed particularly true since all data developed in this study are from subjects in a standing position which is analogous to the supine position.

THE SAMPLE

The sampling strategy was designed to select a small sample of test subjects who are representative of the population of interest (in this case, the U.S. Air Force male flying population specifically, and the U.S. adult male population in general). In most cases a sampling strategy is designed to use either random or matched samples with the intent of gathering descriptive data applicable to the population. In this study we were concerned with finding useful relationships between body size measurements and measurements of mass distribution properties from which population statements can be made. Our primary aim was to obtain a valid correlational analysis for a wide range of body sizes within a workable sample size. From a variety of possible sampling strategies, we elected to use a W-shaped sample (Churchill and McConville, 1976) based on the dimensions of stature and weight. Our intent was to draw ten subjects from each of three discontinuous height/weight strata of the population. These categories were to represent the lower 15%, the middle 20% and the upper 15% of the height/weight distribution found in the 1967 USAF survey of rated officers (Churchill et al., 1977).

In actuality the subject pool did not yield sufficient persons to meet the strict requirements of each category defined by the theoretical sampling strategy. The actual sample is shown plotted on a height/weight bivariate distribution of the USAF flying population (Table 2). The size categories from which the subjects were to be drawn are indicated by the heavy black lines. It will be noted that the actual sample (indicated by ✱) deviates from the sample strategy in that the three subgroups of the sample do not show the marked discontinuity in the height/weight distribution that was originally sought but that, as planned, the sample represents a wide range of body sizes with good representation from the extreme ends of the distribution which are the areas most critical to the solution of design problems. Further, as will be shown in Chapter III, "Data Analysis," the average height and weight of the subjects in this sample closely reflect those of the larger USAF population.

MEASURING AND MARKING

After selection, the subjects were measured for some 75 body dimensions shown on the data sheet reproduced in Figure 5.* After measurements had been completed, targets were placed on each body landmark to facilitate detection during the stereophotometric assessment. Landmarks located on the coronal planes, or sides, of the subjects were marked with three-dimensional

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* Measurement descriptions appear in Appendix A.

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TABLE 2

STUDY SAMPLE PLOTTED ON HEIGHT/WEIGHT

BIVARIATE DISTRIBUTION OF U.S. AIR FORCE MEN (1967)

WEIGHT(LB)

Stratum C

Stratum B

Stratum A

STATURE(CM)

ANTHROPOMETRY--DATA SHEET
MASS DISTRIBUTION OF MALES

Subject No._____   Date_____

Name_____   Age_____

Highest known weight_____   Usual weight   _____   Recent
Weight at 16 years _____   Weight at 23 years_____   weight change_____

Weight	_____	Midthigh Depth	_____
Stature	_____	Calf Depth	_____
Cervicale Height	_____	Ankle Breadth	_____
Tragion Height	_____	Foot Length	_____
Mastoid Height	_____	Foot Breadth	_____
Acromion Height	_____	Axillary Arm Depth	_____
Suprasternale Height	_____	Biceps Depth (relaxed)	_____
Thelion Height	_____	Midforearm Breadth	_____
Tenth Rib Height	_____	Wrist Breadth (bone)	_____
Iliac Crest Height	_____	Hand Length	_____
Omphalion Height	_____	Hand Breadth	_____
Ant Sup Iliac Spine Ht	_____	Meta III-Dactylion Lgth	_____
Symphysion Height	_____	Sitting Height	_____
Trochanterion Height	_____	Head Length	_____
Gluteal Furrow Height	_____	Head Breadth	_____
Tibiale Height	_____	Elbow Br Rt_____ Lt_____	
Fibulare Height	_____	Knee Br Rt_____ Lt_____	
Sphyrion Height	_____	Head Circumference	_____
Acromion-Radiale Length	_____	Neck Circumference	_____
Radiale-Stylion Length	_____	Chest Circumference	_____
Neck Breadth	_____	Tenth Rib Circumference	_____
Biacromial Breadth	_____	Waist Circumference	_____
Chest Breadth	_____	Buttock Circumference	_____
Tenth Rib Breadth	_____	Upper Thigh Circumference	_____
Waist Breadth	_____	Midthigh Circumference	_____
*Bicristale Breadth (bone)	_____	Knee Circumference	_____
Bispinous Breadth	_____	Calf Circ Rt_____ Lt_____	
Bitrochanterion Breadth	_____	Ankle Circumference	_____
Hip Breadth	_____	Arch Circumference	_____
Buttock Depth	_____	Ball of Foot Circ	_____
Gluteal Furrow Depth	_____	Axillary Arm Circ	_____

Figure 5. Data blank.

* This dimension was measured but later eliminated in
  the data analysis.

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Biceps Circ Relaxed

Rt_____ Lt_____

Biceps Circ Flexed

Rt_____ Lt_____

Elbow Circumference _____

Midforearm Circumference _____

Wrist Circumference _____

Hand Circumference _____

Triceps Skinfold _____

Subscapular Skinfold _____

Suprailiac Skinfold _____

Biceps Skinfold _____

LANDMARKS

Nuchale	
Cervicale	
Tenth Rib Level - Midspine	
Post Sup Iliac - Midspine	
Left Gluteal Furrow	
Right Gluteal Furrow	
Lt Post Calcaneus	
Rt Post Calcaneus	
Left Acromion	o
Right Acromion	o
Lt Posterior Scye	
Rt Posterior Scye	
Left Olecranon	
Lt Medial Humeral Epicon	o
Right Radiale	o
Right Olecranon	
Rt Medial Humeral Epicon	o
Left Tenth Rib	o
Right Tenth Rib	o
Left Iliocristale	o
Right Iliocristale	o
Left Trochanterion	o
Right Trochanterion	o
Sellion	
Right Infraorbitale	
Left Infraorbitale	
Right Tragion	o
Left Tragion	o
Right Gonion	o
Left Gonion	o
Adam's Apple (Mid-thyr Cart)	
Right Clavicale	
Left Clavicale	
Suprasternale	
Rt Anterior Scye	
Left Anterior Scye	
Rt Lat Humeral Epicondyle	o
Right Radiale	o
Lt Lat Humeral Epicondyle	o

Left Radiale	o
Rt Ulnar Styloid	o
Rt Radial Styloid	o
Rt Metacarpale V	o
Rt Metacarpale III	
Rt Metacarpale II	o
Left Radial Styloid	o
Left Ulnar Styloid	o
Lt Metacarpale II	o
Lt Metacarpale III	
Lt Metacarpale V	o
Rt Ant Sup Iliac Spine	
Lt Ant Sup Iliac Spine	
Symphysion	
Rt Lat Femoral Epicondyle	o
Right Fibulare	o
Right Infrapatella	
Rt Medial Femoral Epicondyle	o
Right Tibiale	o
Lt Medial Femoral Epicondyle	o
Left Tibiale	o
Left Infrapatella	
Left Lat Femoral Epicondyle	o
Left Fibulare	o
Right Lateral Malleolus	o
Right Medial Malleolus	o
Right Sphyrion	o
Right Metatarsal V	o
Right Metatarsal I	o
Left Medial Malleolus	o
Left Sphyrion	o
Left Lateral Malleolus	o
Left Metatarsal V	o
Left Metatarsal I	o
Right Dactylion	
Left Dactylion	
Right Toe II	
Left Toe II	

Figure 5. (cont'd)

Figure 6. Type image obtained by the stereophotographic process.
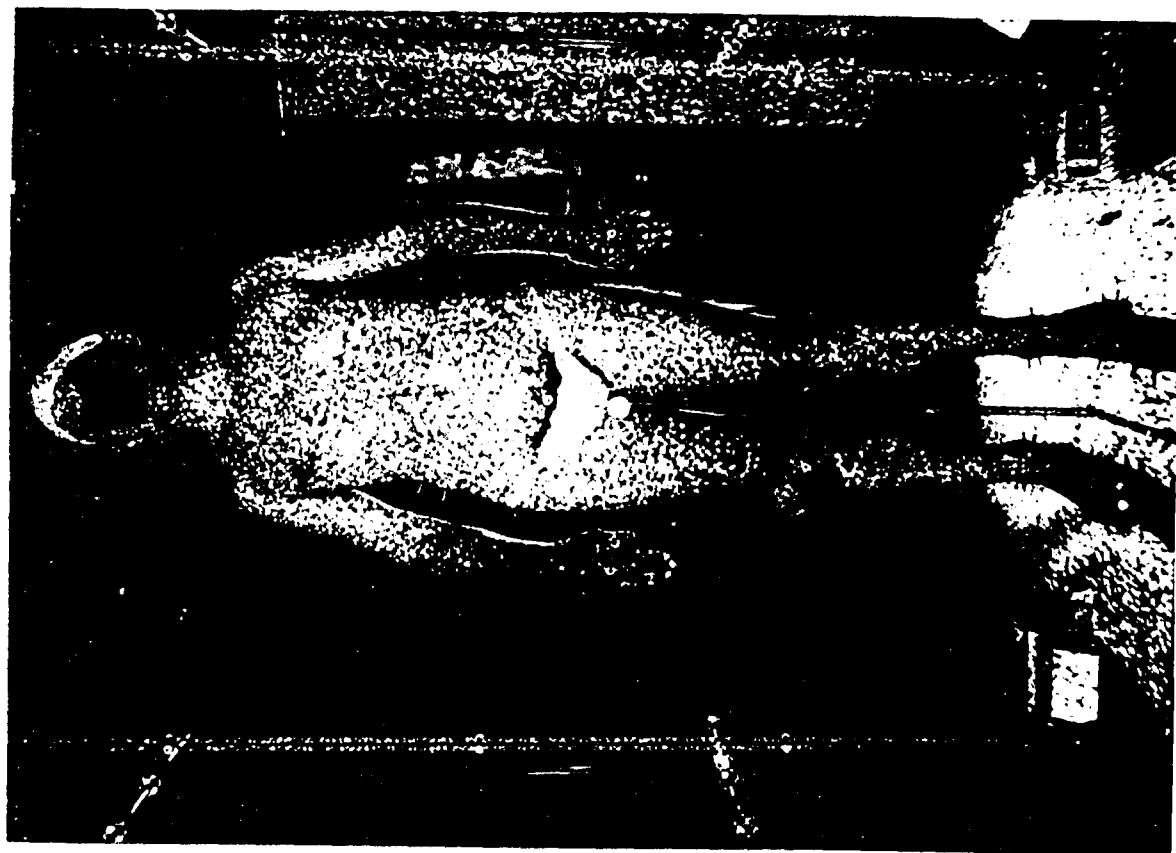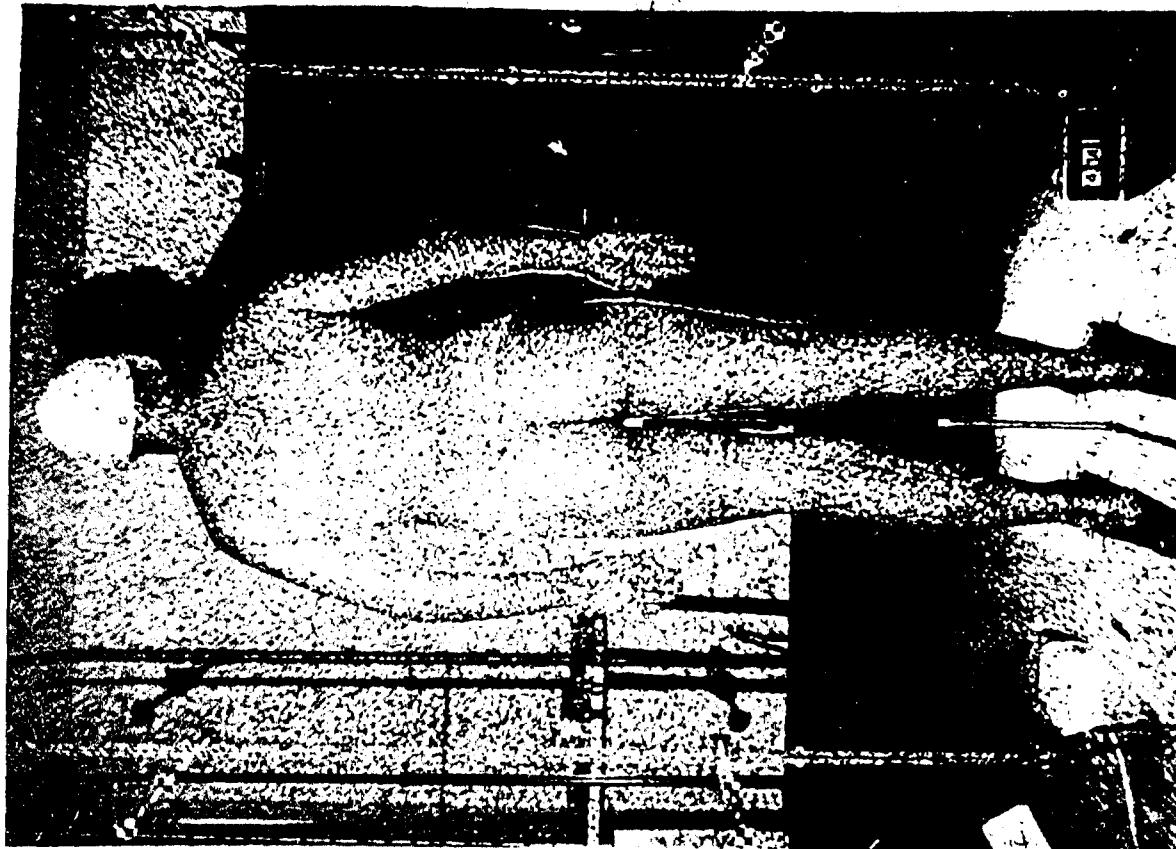
off-sets so as to be visible in the stereometric photos of front and back views. They can be seen most clearly around the right wrist in Figure 6. All the landmarks are listed on the second page of the data sheet (Figure 5) with the symbol (o) denoting the use of off-sets.

THE STEREOPHOTOMETRIC PHOTOGRAPHS

Two pairs of cameras, set up as shown in Figure 7, were used to record the anterio-posterior view of each subject. Control stands (at the subject's sides) provide a "datum" or reference plane which is common to the imagery
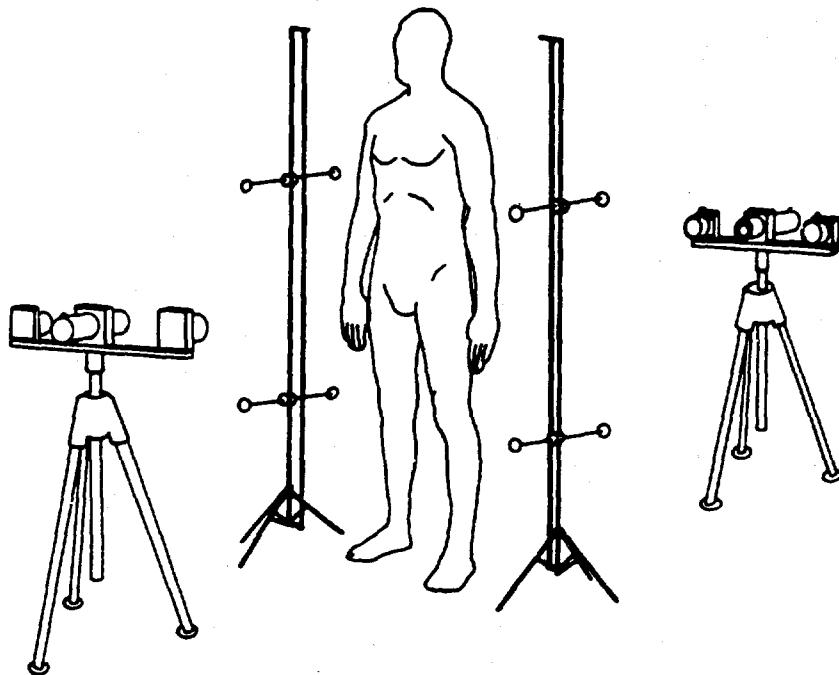
Figure 7. Stereo camera array.*

from each of the opposing stereometric cameras. This permits the analogue transformation of coordinates from each view (i.e., from either front or rear cameras) into a single coordinate system. Control points marked on the body surface in areas common (visible) to both anterior and posterior photographs provide a means for joining the two sets of data points. On opposite sides of the subject, stands support a vertically suspended pair of steel tapes graduated in English and metric units. Perpendicular to the surfaces of the tapes on each side, steel rods of known lengths extend in both directions. High contrast markers affixed to the rods provide points for determining scale at four widely spaced locations in the image space.

* Modified from Herron et al., 1976.

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The stereo cameras are Hasselblad SWC units modified to improve their quality of imagery. Kodak 'M' glass plates (2½" x 0.05") coated with a panchromatic emulsion rated at an effective exposure index of 250 ASA were developed immediately after exposure, before the subject was released, to determine if the imagery was of the desired quality.

For measurements on the Kern PG-2 stereo plotter, all plates were enlarged by a factor of 3.86 onto Kodak aerographic duplicating film with an Estar thick base. The resulting images are similar to those illustrated in Figure 6. The stippling was projected on the body at the time the pictures were taken to increase skin contrast.

The three-dimensional image is viewed through the optics of the stereo plotter and the image of a lighted dot manipulated to indicate the elevation at points on the surface of the stereo image. By recording the position of the floating mark in three directions, the XYZ coordinates of a series of points on the surface are determined.

The coordinates for computation were read for points along parallel cross sections normal to the vertical or laboratory fixed axis. An attachment on the plotter prevents Z axis movement of the base carriage. The Z coordinate is fixed at the uppermost visible level of the segment which corresponds to an even mark on the steel tapes of the control cage. The model is then scanned (from left to right) and a series of XY coordinate points are read with a common Z coordinate. The Z coordinate is then repositioned along the tape until the next interval is found, another series of coordinates is then read, and so on, until the entire segment has been covered. In this study the interval between cross sections was 2.54 cm, except for the head, hands, feet and abdomen segments where the interval was 1.27. The distance between two consecutive points along the perimeter of the cross section ranges from 0.1 to 1.2 cm, with an average of approximately 0.7 cm at object scale. After all segments were read, the data were arranged for processing in the computer.

The individual data points are distributed along cross sections approximately normal to the long axis of the segments. Line segments connecting these points provide a complete cross section of the segment. Given a cross section and assuming constant density, the volume, center of volume, and principal moments and axes of inertia can be calculated. The analytic procedures used in these calculations have been described in detail in a previous publication (Herron et al., 1976).

Thus, the output from the stereophotometric assessment for each subject includes for the total body and each of the primary body segments an estimate of volume, center of volume, principal moments and axes of inertia. These data were then used in the correlational analysis.

There are indications that the stereophotometric technique consistently overestimates values -- in some cases by as much as 5%. The reason for this is unknown and is the subject of continuing investigation. Evidence of this phenomenon in this study is indicated by the lower-than-anticipated volumes for total body density of our subjects as calculated from measured weight and stereophotometrically determined volume (range = .94 - .99; $\bar{x}$ = .96; SD = .01). From a series of skinfold dimensions measured on each subject,

more biologically realistic body densities were calculated ($\bar{x}$ = 1.06; SD = .01). These values, however, are estimates of body densities based on studies where lung and, in some cases, gut gases were subtracted. Therefore, treating the density of the total body and its segments as unity (1.0), as was done in this study, is somewhat compensated for by the fact that, for human engineering purposes, inclusion of the normal gas contents of the body is appropriate.

We also recognize that the center of volume as reported in this study is not coincident with the center of mass of the body or of its segments. Mid-volume of a limb segment is distal to its center of mass (Clauser et al., 1969). While it is important to recognize that an error of constant direction is inherent in using mid-volume to approximate the center of mass, the use of mid-volume is believed to be valid for all practical purposes addressed in this study.

The computer programs developed to calculate many of the data reported in this study were designed so that alternate densities are easily substituted. Table 3 lists data from two studies describing the densities of intact cadavers and their segments. Data describing densities of the torso and its components are not considered as reliable as the values reported for head and limb segments. This is because the gas contents of cadaver torsos are so variable. It is possible to assign density values other than unity and to recompute mass distribution parameters of each segment by simply multiplying the segment volumes by appropriate density values.

TABLE 3

DENSITIES OF THE TOTAL BODY OF CADAVERS
AND THEIR SEGMENTS

	DEMPSTER (1955)		CLAUSER et al. (1969)	
	Mean	SD	Mean	SD
Total Body			1.042	.018
Head			1.071	
Neck and torso			1.023	.032
Head and neck	1.11	.012		
Thorax	0.92	.056		
Abdomino-pelvic	1.01	.014		
Thigh	1.05	.008	1.045	.017
Calf	1.09	.015	1.085	.014
Foot	1.10	.056	1.085	.014
Arm	1.07	.027	1.058	.025
Forearm	1.13	.037	1.099	.018
Hand	1.16	.110	1.108	.019
Torso-limbs	1.07	.016		

Chapter III

DATA ANALYSIS

The material presented in this report is statistical and was obtained from data gathered from 31 subjects. The basic data used in compiling these results consisted of both directly measured and stereophotometrically derived body parameters. In the latter category a number of dimensions and other body characterizing quantities were calculated and compiled.

In all, fourteen tables of data were generated and compiled for each subject. These tables are listed in Appendix C. Only the results considered central to the overall study objectives are presented in the main body of this report. Information for obtaining the remaining data is given in Appendix C.

The data analysis reported here is from two sources: (1) the 87 variables of body size obtained by conventional anthropometry, and (2) the 25 segmental and total body variables of volume and the principal moments and axes of inertia obtained from the stereophotometric technique. Prior to the beginning of the analysis, the data were subjected to extensive editing to identify values which could, on the basis of their distributions, be considered as aberrant. These were then screened to determine if they could be erroneous and corrected where necessary. The editing process, described in detail in Kikta and Churchill (1978), also served to indicate when segment axes were reversed. This occurred when segment shapes were sufficiently symmetrical to yield approximately equal principal moments of inertia with a consequent indeterminacy over which quadrant the principal axis lay in. In certain body segments, such as the forearm and calf, the shapes are sufficiently symmetric to make the X and Y moments, for all practical purposes, essentially identical. In such cases, the segments were rotated about the Z axis to provide consistent alignment to one another.

The primary descriptive statistics (means, standard deviations, etc.) were computed for all variables. It should be noted that the sampling strategy used may have a marked effect on one or more of these descriptive statistics. In this case the attempt to emphasize representation from the extreme ends of the distribution results in a sample which closely reflects mean values of the larger USAF population but whose standard deviations are much larger--as would be expected in assembling a test population which contains a disproportionate number of unusually large and small subjects. The height/weight summary statistics for the sample compare to those of the USAF 1967 survey population as follows:

	Sample (n=31)		USAF 1967 (n=2420)	
	Mean	SD	Mean	SD
Height (cm)	177.49	9.63	177.34	6.19
Weight (lb)	170.38	28.93	173.60	21.44

While the deviations in the mean values for height and weight are relatively small (0.15 cm and 3.22 lb) on the order of 0.08% and 1.85%,

respectively, the differences between standard deviations are quite large. The difference in the standard deviations of height is +3.44 cm or +55.57%; the sample SD for weight is 7.49 pounds or 34.93% larger than the USAF population value.

As with many non-random sampling procedures, the one used here creates a problem in the statistical analysis. It appears that while the mean values are comparable, the standard deviations tend to be inflated. Our concern is with determining and documenting the relationships that exist between the measures of body size as represented by the anthropometry and the mass distribution parameters as represented by the measures of volume, principal moments and principal axes of inertia. For these purposes, we believe that the inflated standard deviations do not present a problem.

Summary statistics for the anthropometry of the study sample are presented in Table 4. Variables #2 through #77 were measured on the subjects and variables #78 through #87 were derived from the measured variables as:

(78) Head Ht = (3) Stature minus (6) Mastoid Ht

(79) Neck Lgth = (6) Mastoid Ht minus (4) Cervicale Ht

(80) Torso Lgth = (4) Cervicale Ht minus (16) Gluteal Furrow Ht

(81) Thorax Lgth = (4) Cervicale Ht minus (10) Tenth Rib Ht

(82) Abdomen Lgth = (10) Tenth Rib Ht minus (11) Iliac Crest Ht

(83) Pelvic Lgth = (11) Iliac Crest Ht minus (16) Gluteal Furrow Ht

(84) Thigh Flap Lgth = (13) Ant Sup Iliac Spine Ht minus
                           (16) Gluteal Furrow Ht

(85) Thigh Lgth = (15) Trochanteric Ht minus (17) Tibiale Ht

(86) Calf Lgth = (17) Tibiale Ht minus (19) Sphyrion Ht

(87) Forearm-Hand Lgth = (21) Radiale-Stylion Lgth plus
                            (41) Hand Lgth

The volume, principal moments and axes of inertia are reported for each segment and for the total body in Tables 5 through 29 which follow. These results are presented in a two-page format for each body segment. Results for the head segment are given in Table 5. At the top of the left-hand page is a line drawing of the segment. Two axis systems are shown on the line drawing; the first, the X_a, Y_a, Z_a, is the anatomical axis system based on the skeletal landmarks. The second axis system, X_p, Y_p, and Z_p, the principal axes of inertia, is depicted originating at the center of volume of the segment with its orientation illustrating the general relationship of this axis system to the anatomical axis system.

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TABLE 4

DESCRIPTIVE STATISTICS FOR ANTHROPOMETRIC VARIABLES (n=31)*

NO.	VARIABLE NAME	MEAN	STD DEV	V-I[†]	V-II[†]	V[†]
1	AGE	27.45	5.64	1.22	4.57	20.6%
2	WEIGHT	1703.84	289.30	.56	2.44	17.0%
3	STATURE	1774.90	96.27	.18	1.77	5.4%
4	CERVICALE HT	1526.59	92.81	.22	1.80	6.1%
5	TRAGION HT	1638.10	94.78	.14	1.81	5.8%
6	MASTOID HT	1608.35	93.56	.14	1.75	5.8%
7	ACROMIAL HT	1448.19	93.42	.15	1.81	6.5%
8	SUPRASTERNALE HT	1443.90	85.52	.08	1.90	5.9%
9	THELION HT	1287.97	76.50	.09	1.96	5.9%
10	TENTH RIB HT	1123.52	71.88	.16	1.95	6.4%
11	ILIAC CREST HT	1073.45	69.70	.05	2.02	6.5%
12	OMPHALION HT	1065.23	69.63	.15	1.97	6.5%
13	ANT SUP ILIAC SP H	997.94	65.69	.11	2.07	6.6%
14	SYMPH HT	914.77	61.23	.12	1.91	6.7%
15	TROCHANTERION HT	943.58	63.90	.17	1.95	6.8%
16	GLUTEAL FURROW HT	815.13	57.81	.00	1.98	7.1%
17	TIBIAL HT	478.10	34.24	.05	2.46	7.2%
18	FIBULAR HT	479.19	34.90	.41	2.19	7.3%
19	SPHYRION HT	70.74	6.82	.26	2.68	9.6%
20	ACROMIAL-RAD LN	333.94	24.59	-.20	1.92	7.4%
21	RADIAL-STYLION LN	270.45	18.15	.23	1.96	6.7%
22	NECK BREADTH	122.87	8.66	.76	2.73	7.1%
23	BIACROMIAL BREADTH	415.84	23.28	.04	2.21	5.6%
24	CHEST BREADTH	331.94	21.42	.10	2.56	6.5%
25	10TH RIB BREADTH	298.45	23.28	-.29	2.27	7.8%
26	WAIST BREADTH	312.29	27.10	-.12	2.22	8.7%
27	BISPINOUS BREADTH	222.94	21.67	-.20	3.43	9.7%
28	BITROCHANTERIC BR	317.61	19.60	.25	2.79	6.2%
29	HIP BREADTH	346.23	23.31	.32	3.30	6.7%
30	BUTTOCK DEPTH	240.84	20.84	.60	2.60	8.7%
31	GLUTEAL FURROW DPT	193.84	14.42	.18	2.53	7.4%
32	MIDTHIGH DEPTH	174.03	10.00	.69	2.46	5.7%
33	CALF DEPTH	120.23	6.85	.74	3.23	5.7%
34	ANKLE BREADTH	59.00	4.29	.02	1.93	7.3%
35	FOOT LENGTH	266.13	16.44	.61	3.30	6.2%
36	FOOT BREADTH	104.94	5.85	.28	2.30	5.6%
37	AXILLARY ARM DEPTH	124.90	12.47	.42	4.33	10.0%
38	BICEPS DPTH (RELX)	108.26	11.40	.98	4.54	10.5%
39	MIDFOREARM BREADTH	79.48	6.72	.11	5.15	8.5%
40	WRIST BREADTH	55.42	3.71	.51	2.70	6.7%
41	HAND LENGTH	189.39	10.40	.53	2.85	5.5%
42	HAND BREADTH	86.35	4.88	.24	2.43	5.7%
43	META-3-DACTY LNGTH	109.42	6.48	.47	4.26	5.9%
44	SITTING HT	930.13	47.02	.24	2.32	5.1%
45	HEAD LENGTH	199.32	8.01	-.26	3.11	4.0%

* Age in years, weight in tenths of pounds and all others in mm with the exception of skinfold measurements given in tenths of mm.

† V-I and V-II are measures of the symmetry and kurtosis of the distribution; V is the coefficient of variation

TABLE 4 (cont'd)

NO.	VARIABLE NAME	MEAN	STD DEV	V-I[†]	V-II[†]	V[†]
46	HEAD BREADTH	153.23	5.18	-.27	2.16	3.4%
47	ELBOW BREADTH RT	70.90	4.45	.51	2.35	6.3%
48	ELBOW BREADTH LF	70.48	4.29	.49	2.58	6.1%
49	KNEE BREADTH RT	96.39	5.67	.13	2.81	5.9%
50	KNEE BREADTH LF	95.68	5.79	.41	3.21	6.1%
51	HEAD CIRC	572.74	14.33	.38	2.17	2.5%
52	NECK CIRC	376.71	26.98	.61	2.54	7.2%
53	CHEST CIRC	965.13	75.69	.31	2.45	7.8%
54	10TH RIB CIRC	821.48	71.56	.14	2.14	8.7%
55	WAIST CIRC	857.00	78.79	.01	2.09	9.2%
56	BUTTOCK CIRC	952.87	63.90	.29	2.41	6.7%
57	UPPER THIGH CIRC	570.23	39.70	.31	2.69	7.0%
58	MIDTHIGH CIRC	528.97	30.05	.77	3.05	5.7%
59	KNEE CIRC	374.10	24.99	.39	2.36	6.7%
60	CALF CIRC RT	379.55	20.76	.67	2.66	5.5%
61	CALF CIRC LF	374.23	32.05	-1.62	9.06	8.6%
62	ANKLE CIRC	224.29	12.88	.21	2.51	5.7%
63	ARCH CIRC	260.06	24.50	3.19	15.88	9.4%
64	BALL OF FOOT CIRC	257.32	23.93	2.93	14.00	9.3%
65	AXILLARY ARM CIRC	319.10	26.20	.54	3.60	8.2%
66	BICEPS CIRC RLX RT	300.90	25.79	1.33	5.79	8.6%
67	BICEPS CIRC RLX LF	298.45	24.93	1.19	5.14	8.4%
68	ELBOW CIRC	265.74	18.47	.52	2.99	7.0%
69	MIDFOREARM CIRC	234.16	15.55	.62	4.78	6.6%
70	WRIST CIRC	169.94	10.44	.48	2.95	6.1%
71	HAND CIRC	208.68	10.84	.16	2.54	5.2%
72	TRICEPS SKINFOLD	94.35	26.02	.43	2.93	27.6%
73	SUBSCAPULAR SKINF	120.97	52.39	1.62	5.16	43.3%
74	SUPRAILIAC SKINF	152.42	61.45	.46	2.20	40.3%
75	BICEPS SKINFOLD	37.42	17.36	1.80	6.28	46.4%
76	BICEPS CIRC FLEX R	322.74	25.70	1.23	5.30	8.0%
77	BICEPS CIRC FLEX L	319.29	25.50	1.45	6.26	8.0%
78	HEAD HT	166.55	7.75	.37	2.44	4.7%
79	NECK LENGTH	81.77	11.71	.18	4.89	14.3%
80	TORSO LENGTH	711.45	39.79	.47	2.12	5.6%
81	THORAX LENGTH	403.06	26.86	.21	2.61	6.7%
82	ABDOMEN LENGTH	50.06	12.57	.82	3.64	25.1%
83	PELVIC LENGTH	258.32	16.66	.10	3.26	6.4%
84	THIGH FLAP LENGTH	182.81	16.20	.24	2.50	8.9%
85	THIGH LENGTH	465.49	34.19	.13	1.76	7.3%
86	CALF LENGTH	407.35	30.52	-.03	2.75	7.5%
87	FOREARM-HAND LNGTH	459.84	27.18	.32	2.32	5.9%

Adjacent to the sketch is a tabulation of the range, mean and standard deviation of selected measured dimensions--in this case, head length, breadth, circumference, and height. Following this are similar statistics for the segment volume. Below the sketch are given the range, mean and standard deviation for the location of the center of volume from the anatomical axis origin in the X_a, Y_a, and Z_a notation. The mean and standard deviation are similarly given for the location of the center of volume from a number of anatomical landmarks, once again using the notation of the anatomical axis, X_a, Y_a, and Z_a. For example, the third and fourth lines of this set of data in Table 5 show that the origin of the principal axis of inertia lies .85 cm behind, essentially equally distant between and 3.13 cm above the left and right tragion landmarks.

The range, mean and standard deviation for the principal moments of inertia are then listed and are followed by the mean and standard rotational deviation in degrees of the principal axis of inertia with respect to the orientation of the anatomical axis system. (Computations used to arrive at the mean and standard rotational deviation of the principal axis systems are discussed in Appendix B.) The first line of the principal axes tabulation indicates that the mean X principal axis lies 36.13° from the anatomical X axis, 86.95° from the anatomical Y axis and 54.04° from the anatomical Z axis.

The second page of the table is devoted to a series of regression equations for predicting volume and principal moments of inertia from various anthropometric dimensions. The first section of the table tabulates the regression equations using stature and weight as predictor values. While these anthropometric variables do not necessarily provide the best estimates possible, they are provided because both stature and weight are generally known or readily obtainable for most populations of interest. These regressions are given in the form:

$$\text{Predicted Variable} = \text{Coefficient} \cdot \text{Stature} \pm \text{Coefficient} \cdot \text{Weight} \pm \text{Constant}$$

The multiple correlation coefficient (R) and the standard error of estimate (SE EST) are given on the extreme right of the line. The standard error of estimate is given as a percent of the predicted variable mean value rather than in its more usual numerical value.

These regression equations are followed by a series of multistep regression equations which use stature, weight and other segmental anthropometric variables as predictors. These regressions were obtained using a standard type of BMD stepwise regression computer program which selects those body dimensions from a given set having the maximum power to predict a given segment volume or principal moment of inertia. The initial anthropometric variable is selected on the basis of having the largest correlation coefficient with the predicted variable and then partial correlation coefficients are computed from which the variable having the second greatest predictive power is selected. The process can be continued to select the next predictor and so on. The predictive equations presented here were restricted to three steps or less as they are cumbersome to use beyond a three-step level and have

rapidly decreasing efficiency (in terms of prediction) after a certain level is reached. In some instances, a second or third step equation will not be listed as it was found to offer no practical advantage over the previous one- or two-step equation. The cut-off point in terms of the number of steps to be reported was based on the continued decrease in the resulting standard error of estimate.

The body size variables considered in the development of these equations were restricted to those measured directly on the segment involved plus stature and weight. The latter were included because as measures of overall mass distribution they may be better predictors than any other single variable.

In theory, the predictive powers of the regression equations should be improved by raising the anthropometric variables to their fourth power before initiating the stepwise analysis. In reality, the improvement obtained was essentially insignificant with the increase of the multiple correlation coefficient averaging +.009 with a standard deviation ±.007. Such a low level of improvement in the results does not warrant increasing the complexity of the regression equation with a power function and was therefore dropped from further consideration.

This data format is repeated for each of the 25 separate segments.

TABLE 5

HEAD

```
ANTHROPOMETRY
OF SEGMENT   RANGE        MEAN     S.D.
HEAD LGTH 17.8- 21.6     19.93     .80
HEAD BR   14.2- 16.1     15.32     .52
HEAD CIRC 55.2- 60.4     57.27    1.43
HEAD HT   15.3- 18.2     16.65     .77
```

```
         HEAD VOLUME
   RANGE              MEAN      S.D.
3,795 - 5,069        4,369      295
```
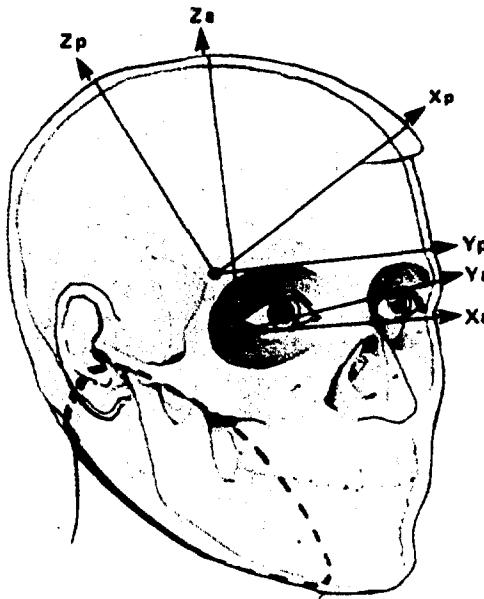


```
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
              RANGE              MEAN      S.D.
X-AXIS   -1.79   -    .53       -.85       .49
Y-AXIS    -.75   -    .60        .01       .31
Z-AXIS    2.07   -   4.05       3.13       .48
```

```
LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS
                  X-MEAN  X-S.D.  Y-MEAN  Y-S.D.  Z-MEAN  Z-S.D.
NUCHALE            8.77     .76    -.54    .59     6.07     .98
SELLION           -9.88     .40     .01    .31     1.29     .77
LEFT TRAGION       -.85     .49   -7.57    .36     3.13     .48
RIGHT TRAGION      -.85     .49    7.62    .32     3.13     .48
R INFRAORBITALE   -8.08     .36    3.27    .35     3.13     .48
```

```
THE PRINCIPAL MOMENTS OF INERTIA
              RANGE               MEAN      S.D.
X-AXIS   155,880 - 260,023     204,117    25,449
Y-AXIS   174,248 - 310,090     232,888    31,815
Z-AXIS   122,517 - 191,634     150,832    15,571
```

```
PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
         COSINE MATRIX EXPRESSED IN DEGREES
        X        Y        Z
X    36.13    86.95    54.04    STD. DEV. OF ROT. X =   2.31
Y    93.75     3.75    90.02    STD. DEV. OF ROT. Y =   6.89
Z   125.88    92.19    35.96    STD. DEV. OF ROT. Z =   4.31
```

HEAD: REGRESSION EQUATIONS

HEAD VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	6.84 +	2.05 +	2,806	.414	6.4%
X MOMENT	=	859 +	86 +	36,972	.416	11.7%
Y MOMENT	=	1,097 +	103 +	20,735	.419	12.8%
Z MOMENT	=	216 +	168 +	83,847	.437	9.6%

HEAD VOLUME FROM:

HEAD CIRC	HEAD LGTH		CONSTANT	R	SE EST
160.01		-	4,800.09	.776	4.3%
216.18 -	121.84	-	5,593.60	.798	4.2%

HEAD X MOMENT FROM:

HEAD CIRC	HEAD BR		CONSTANT	R	SE EST
13,491		-	568,894	.759	8.3%
11,639 +	10,605	-	625,049	.783	8.0%

HEAD Y MOMENT FROM:

HEAD CIRC		CONSTANT	R	SE EST
17,924	-	794,181	.807	8.2%

HEAD Z MOMENT FROM:

HEAD CIRC	HEAD LGTH		CONSTANT	R	SE EST
8,493		-	335,264	.780	6.6%
11,857 -	7,320	-	382,935	.809	6.3%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 6

NECK

ANTHROPOMETRY

OF SEGMENT	RANGE	MEAN	S.D.
NECK CIRC	33.7- 43.7	37.67	2.70
NECK BR	10.9- 14.3	12.29	.87
NECK LGTH	4.8- 11.5	8.18	1.17

NECK VOLUME

RANGE	MEAN	S.D.
721 - 1,552	1,043	182
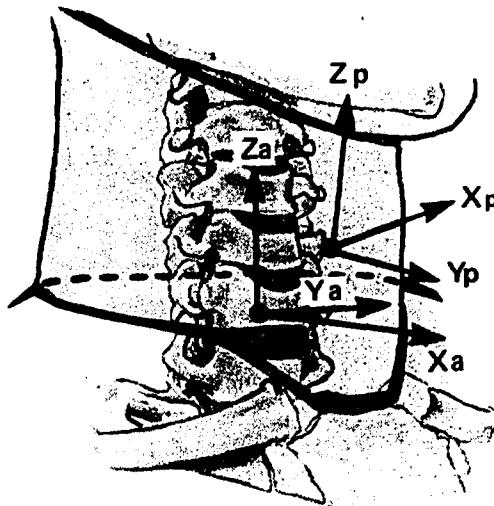
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	4.17 -	7.31	5.72	.71
Y-AXIS	-1.29 -	.59	-.18	.41
Z-AXIS	3.93 -	6.05	4.98	.44

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
CERVICALE	5.72	.71	-.18	.41	4.98	.44
LEFT CLAVICALE	-7.16	.80	-2.54	.46	4.96	.52
RIGHT CLAVICALE	-7.38	.84	2.26	.58	5.00	.46
MID THYROID CART	-6.24	.56	-.18	.41	-.66	1.06
SUPRASTERNALE	-6.28	.81	-.18	.41	6.09	.66

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE		MEAN	S.D.
X-AXIS	9,205 -	33,649	16,824	5,277
Y-AXIS	10,163 -	36,754	20,250	5,782
Z-AXIS	13,986 -	49,238	25,057	7,345

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z		
X	12.75	80.08	82.08	STD. DEV. OF ROT. X =	9.37
Y	99.29	10.54	94.92	STD. DEV. OF ROT. Y =	7.92
Z	98.65	86.48	9.34	STD. DEV. OF ROT. Z =	11.84

NECK: REGRESSION EQUATIONS

NECK VOLUME AND MOMENTS FROM STATURE AND WEIGHT

	STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME =	-5.50 +	6.32 +	943	.749	12.0%
X MOMENT =	-142 +	173 +	12,401	.723	22.4%
Y MOMENT =	-222 +	212 +	23,551	.741	19.9%
Z MOMENT =	-361 +	301 +	37,865	.778	19.1%

NECK VOLUME FROM:

NECK CIRC	WEIGHT	NECK BR	CONSTANT	R	SE EST
52.99		-	954.51	.785	11.0%
36.89 +	1.83	-	659.40	.803	10.8%
11.37 +	2.03 +	83.40 -	756.87	.823	10.4%

NECK X MOMENT FROM:

NECK BR	WEIGHT	NECK LGTH	CONSTANT	R	SE EST
4,752		-	41,620	.780	20.0%
3,336 +	60	-	34,491	.815	18.8%
3,125 +	64 +	597 -	37,472	.825	18.7%

NECK Y MOMENT FROM:

NECK CIRC	WEIGHT	NECK BR	CONSTANT	R	SE EST
1,583		-	39,417	.738	19.6%
945 +	73	-	27,718	.767	19.0%
190 +	78 +	2,467 -	30,602	.785	18.6%

NECK Z MOMENT FROM:

NECK CIRC	NECK BR	WEIGHT	CONSTANT	R	SE EST
2,250		-	59,779	.827	16.8%
1,206 +	3,663	-	65,463	.850	16.0%
532 +	3,939 +	68 -	54,971	.864	15.6%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 7

THORAX

ANTHROPOMETRY

OF SEGMENT	RANGE	MEAN	S.D.
CHEST CIR	82.6-113.8	96.51	7.57
CHEST BR	28.4- 37.9	33.19	2.14
THORAX L	35.2- 46.5	40.31	2.69
10 RIB BR	24.6- 33.6	29.85	2.33
10 RIB C	70.1- 95.7	82.15	7.16
SUBSCAP SKINFOLD			
	7.0- 26.0	12.10	5.24

THORAX VOLUME

RANGE	MEAN	S.D.
16,452 - 35,321	24,385	4,649
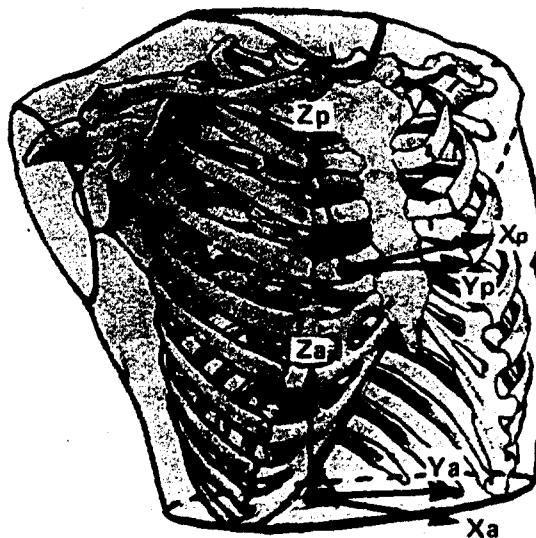
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE			MEAN	S.D.
X-AXIS	4.22	-	7.07	5.80	.73
Y-AXIS	-.54	-	.49	.13	.27
Z-AXIS	17.12	-	21.98	18.99	1.20

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
CERVICALE	5.80	.73	.13	.27	-21.62	1.76
10TH RIB MIDSPINE	5.80	.73	.13	.27	18.99	1.20
LEFT ACROMIALE	3.32	1.55	-20.16	1.27	-15.23	1.92
RIGHT ACROMIALE	1.82	1.99	20.75	1.06	-14.23	1.62
SUPRASTERNALE	-6.07	.68	.13	.27	-14.23	1.04

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE		MEAN	S.D.
X-AXIS	2,724,311 - 8,323,236		4,774,889	1,497,622
Y-AXIS	1,913,036 - 6,344,398		3,512,342	1,140,605
Z-AXIS	1,505,047 - 5,301,733		2,959,363	944,269

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z	
X	14.43	90.50	75.58	STD. DEV. OF ROT. X = 4.31
Y	90.06	2.22	87.79	STD. DEV. OF ROT. Y = 2.85
Z	104.43	92.16	14.60	STD. DEV. OF ROT. Z = 2.74

THORAX: REGRESSION EQUATIONS

THORAX VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	-22.71 +	163.68 +	524	.976	4.3%
X MOMENT	=	8,183 +	47,484 -	4,768,961	.965	8.5%
Y MOMENT	=	3,738 +	36,636 -	3,393,924	.958	9.6%
Z MOMENT	=	-14,325 +	36,254 -	675,725	.980	6.5%

THORAX VOLUME FROM:

WEIGHT	CHEST CIR	THORAX LGTH	CONSTANT	R	SE EST
156.80		-	2,334.31	.976	4.2%
109.92 +	189.96	-	12,676.98	.981	3.8%
75.01 +	236.12 +	316.66 -	23,943.81	.987	3.2%

THORAX X MOMENT FROM:

WEIGHT	THORAX LGTH	CHEST BR	CONSTANT	R	SE EST
49,963		-	3,738,760	.965	8.4%
39,681 +	138,438	-	7,565,763	.977	7.0%
32,621 +	143,486 +	104,738 -	10,043,411	.979	6.7%

THORAX Y MOMENT FROM:

WEIGHT	THORAX LGTH	STATURE	CONSTANT	R	SE EST
37,768		-	2,923,320	.958	9.5%
28,924 +	119,075	-	6,215,043	.973	7.8%
33,058 +	136,460 -	17,912 -	4,440,692	.974	7.7%

THORAX Z MOMENT FROM:

WEIGHT	CHEST CIR	THORAX LGTH	CONSTANT	R	SE EST
31,916		-	2,479,038	.978	6.8%
20,483 +	46,325	-	5,001,216	.986	5.6%
15,461 +	52,965 +	45,554 -	6,622,028	.988	5.1%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 8

ABDOMEN

ANTHROPOMETRY
OF SEGMENT	RANGE		MEAN	S.D.
ABDOMEN L	3.0-	8.2	5.01	1.26
WAIST CIR	72.3-	99.7	85.70	7.88
10 RIB BR	24.6-	33.6	29.85	2.33
10 RIB C	70.1-	95.7	82.15	7.16
WAIST BR	26.1-	35.6	31.23	2.71
SUPRAIL'C SKINFOLD				
	6.0-	28.0	15.24	6.14

ABDOMEN VOLUME
RANGE		MEAN	S.D.
915 -	3,912	2,339	693
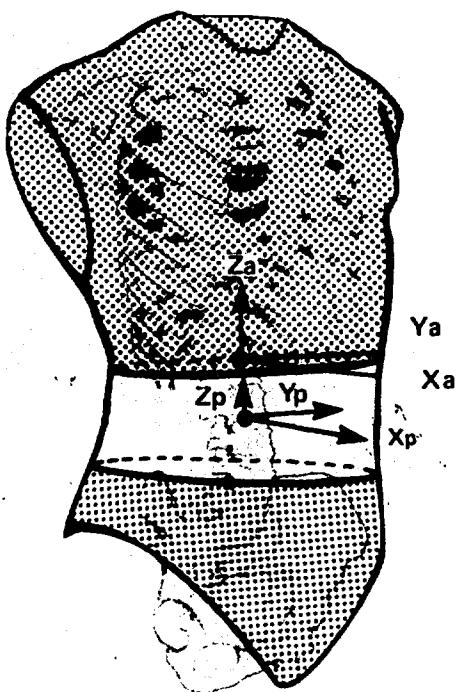
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
	RANGE		MEAN	S.D.
X-AXIS	-4.82	- 1.54	-.40	1.14
Y-AXIS	-2.57	- 2.25	.50	.86
Z-AXIS	-3.65	- -1.15	-2.42	.67

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS
	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
L ILIOCRISTALE	.09	1.03	-15.69	1.27	2.15	.64
R ILIOCRISTALE	.28	1.26	16.17	1.43	2.63	.82
LEFT 10TH RIB	-.40	1.14	-15.00	1.26	-2.42	.67
RIGHT 10TH RIB	-.40	1.14	15.21	1.33	-2.42	.67
P S IL'C MDSPINE	11.09	1.09	.59	.89	5.72	1.58

THE PRINCIPAL MOMENTS OF INERTIA
	RANGE		MEAN	S.D.
X-AXIS	45,129 -	327,248	156,228	66,349
Y-AXIS	20,339 -	207,761	86,397	41,900
Z-AXIS	64,711 -	465,963	235,236	102,995

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES
	X	Y	Z	
X	2.61	91.47	92.15	STD. DEV. OF ROT. X = 1.75
Y	88.51	1.61	89.38	STD. DEV. OF ROT Y = 4.64
Z	87.86	90.68	2.24	STD. DEV. OF ROT. Z = 4.36

ABDOMEN: REGRESSION EQUATIONS

ABDOMEN VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	-23.05 +	19.42 +	3,121	.536	25.9%
X MOMENT	=	-2,124 +	2,218 +	155,225	.698	31.5%
Y MOMENT	=	-1,838 +	1,481 +	160,313	.662	37.6%
Z MOMENT	=	-3,865 +	3,625 +	303,513	.705	32.1%

ABDOMEN VOLUME FROM:

ABDOMEN LGTH	WAIST CIR	WEIGHT	CONSTANT	R	SE EST
396.95		+	354.65	.720	20.9%
298.13 +	44.39	-	2,955.60	.861	15.6%
290.54 +	70.58 -	7.97 -	3,803.99	.875	15.1%

ABDOMEN X MOMENT FROM

WAIST CIR	ABDOMEN LGTH	SUPRAIL'C SKINFOLD	CONSTANT	R	SE EST
6,993		-	443,070	.830	24.1%
5,743 +	22,063	-	446,249	.918	17.5%
4,678 +	21,771 +	1,717 -	379,651	.922	17.3%

ABDOMEN Y MOMENT FROM

10 RIB C	ABDOMEN LGTH	SUPRAIL'C SKINFOLD	CONSTANT	R	SE EST
4,789		-	306,792	.818	28.4%
3,807 +	14,797	-	300,104	.915	20.2%
2,659 +	14,558 +	1,746 -	231,263	.929	18.9%

ABDOMEN Z MOMENT FROM

WAIST CIR	ABDOMEN LGTH	SUPRAIL'C SKINFOLD	CONSTANT	R	SE EST
11,075		-	713,850	.847	23.7%
9,103 +	34,803	-	718,864	.936	16.0%
7,198 +	34,280 +	3,071 -	599,736	.942	15.5%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 9

PELVIS

ANTHROPOMETRY
```
OF SEGMENT  RANGE       MEAN   S.D.
BUTTOCK C  84.1-109.0   95.29  6.39
BUTT'K DP  20.6- 29.1   24.08  2.08
BISPIN BR  16.8- 27.0   22.29  2.17
PELVIC L   21.9- 29.7   25.83  1.67
HIP BR     30.0- 40.8   34.62  2.33
SUPRAIL'C SKINFOLD
            6.0- 28.0   15.24  6.14
```

```
        PELVIS VOLUME
     RANGE            MEAN    S.D.
7,148 - 16,400      11,390   2,565
```
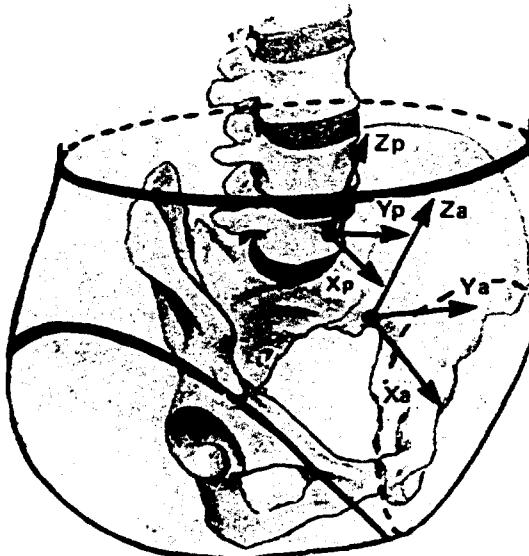

LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
```
              RANGE            MEAN      S.D.
X-AXIS  -10.02   -  -6.96     - 8.18     .82
Y-AXIS    -.73   -    .74       .05      .36
Z-AXIS   -1.57   -   5.18      1.07     1.17
```

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS
```
                  X-MEAN  X-S.D.  Y-MEAN  Y-S.D.  Z-MEAN  Z-S.D.
LEFT ASIS          -8.18    .82   -11.16   1.06    1.07    1.17
RIGHT ASIS         -8.18    .82    11.28   1.17    1.07    1.17
POS SUP ILIAC MS    7.17   1.20     .05     .36   -8.30    1.08
SYMPHYSION         -8.18    .82     .13     .52    9.71    1.37
```

THE PRINCIPAL MOMENTS OF INERTIA
```
            RANGE                   MEAN       S.D.
X-AXIS  442,667 - 1,737,411       993,154    357,943
Y-AXIS  426,544 - 1,722,636       909,728    349,198
Z-AXIS  491,319 - 2,066,561     1,148,135    435,481
```

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES
```
      X       Y       Z
X   11.57  100.31   84.80    STD. DEV. OF ROT. X =  3.24
Y   79.62   10.38   90.26    STD. DEV. OF ROT. Y = 12.49
Z   95.07   88.81    5.21    STD. DEV. OF ROT. Z = 10.35
```

PELVIS: REGRESSION EQUATIONS

PELVIS VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	-68.97 +	98.98 +	6,765	.887	18.7%
X MOMENT	=	-10,283 +	14,215 +	396,174	.984	15.9%
Y MOMENT	=	-10,851 +	13,750 +	492,711	.876	19.2%
Z MOMENT	=	-14,684 +	17,498 +	772,875	.877	18.8%

PELVIS VOLUME FROM:

BUTTOCK C	SUPRAIL'C SKINFOLD	BUTT'K DP	CONSTANT	R	SE EST
362.75		-	23,179.36	.984	9.8%
279.79 +	138.28	-	17,375.21	.940	7.9%
192.98 +	103.29 +	392.86 -	18,838.43	.954	7.1%

PELVIS X MOMENT FROM:

BUTTOCK C	SUPRAIL'C SKINFOLD	BUTT'K DP	CONSTANT	R	SE EST
51,216		-	3,887,786	.914	14.8%
40,473 +	17,987	-	3,136,895	.945	12.2%
30,171 +	13,754 +	46,623 -	3,214,802	.955	11.3%

PELVIS Y MOMENT FROM:

BUTT'K DP	WEIGHT	SUPRAIL'C SKINFOLD	CONSTANT	R	SE EST
152,381		-	2,762,656	.909	16.2%
101,293 +	4,516	-	2,301,008	.935	14.1%
79,999 +	4,294 +	11,786 -	1,929,018	.947	13.0%

PELVIS Z MOMENT FROM:

BUTT'K DP	BUTTOCK C	SUPRAIL'C SKINFOLD	CONSTANT	R	SE EST
191,408		-	3,464,807	.916	15.5%
115,988 +	29,237	-	4,433,412	.945	12.8%
89,240 +	26,661 +	16,528 -	3,794,526	.960	11.2%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 10

RIGHT UPPER ARM

ANTHROPOMETRY

OF SEGMENT	RANGE	MEAN	S.D.
AX ARM C	26.8- 39.5	31.91	2.62
BICEPS C RELAXED			
	26.3- 39.2	30.09	2.58
BICEPS C FLEXED			
	28.3- 41.1	32.27	2.57
ACROMIAL-RADIAL LGTH			
	28.3- 37.1	33.39	2.46
ELBOW CIR	23.1- 31.4	26.57	1.85
BICEPS DP -RELAXED			
	9.3- 14.5	10.83	1.14
ELBOW BR	6.4- 8.1	7.09	.44
BICEPS SF	2.0- 10.0	3.74	1.74
TRICEP SF	5.0- 16.5	9.44	2.60
AX ARM DP	9.6- 16.3	12.49	1.25

RIGHT UPPER ARM VOLUME

RANGE	MEAN	S.D.
1,259 - 3,150	1,955	389
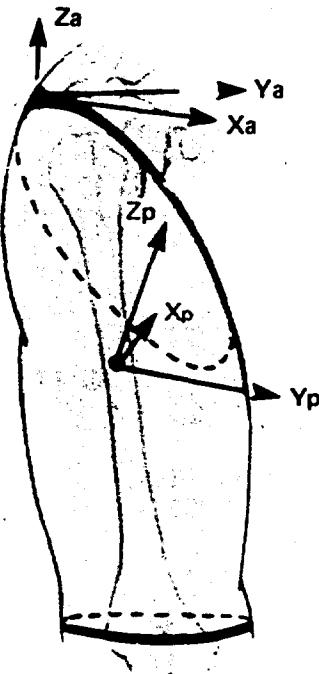
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	-2.14 -	-.92	-1.60	.34
Y-AXIS	-4.04 -	-2.28	-3.05	.41
Z-AXIS	-20.53 -	-14.28	-17.18	1.53

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
RIGHT ACROMIALE	1.60	.34	3.05	.41	-17.18	1.53
RIGHT OLECRANON	4.00	.38	-2.87	.62	13.55	1.11
R MED HUM EPICON	1.60	.34	-5.06	.55	14.08	1.18
R LAT HUM EPICON	1.60	.34	3.05	.41	14.42	1.09
RIGHT RADIALE	1.90	.60	2.46	.67	15.76	1.17

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE	MEAN	S.D.
X-AXIS	57,846 - 250,155	127,515	42,915
Y-AXIS	61,213 - 276,453	135,568	46,612
Z-AXIS	12,235 - 60,858	25,859	9,412

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z			
X	25.63	115.53	87.92	STD. DEV. OF ROT. X =	1.29
Y	64.39	26.56	96.58	STD. DEV. OF ROT. Y =	1.85
Z	89.03	83.17	6.90	STD. DEV. OF ROT. Z =	9.24

RIGHT UPPER ARM: REGRESSION EQUATIONS

RIGHT UPPER ARM VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT		CONSTANT	R	SE EST*
VOLUME	=	-2.14 +	13.25 +		76	.937	7.2%
X MOMENT	=	934 +	1,094 -		224,626	.932	12.6%
Y MOMENT	=	627 +	1,304 -		198,020	.929	13.2%
Z MOMENT	=	-338 +	391 +		19,102	.900	16.4%

RIGHT UPPER ARM VOLUME FROM:

WEIGHT	BICEPS C FLEXED R	ACROMIAL- RADIAL L		CONSTANT	R	SE EST
12.51			-	193.15	.936	7.1%
7.59 +	68.34		-	1,545.38	.970	5.0%
2.54 +	84.86 +	52.47	-	2,970.77	.983	3.9%

RIGHT UPPER ARM X MOMENT FROM:

WEIGHT	ACROMIAL- RADIAL L	BICEPS C FLEXED R		CONSTANT	R	SE EST
1,377			-	107,347	.928	12.8%
888 +	6,795		-	249,297	.949	11.0%
159 +	9,700 +	6,912	-	446,887	.973	8.1%

RIGHT UPPER ARM Y MOMENT FROM:

WEIGHT	TRICEP SF	AX ARM DP		CONSTANT	R	SE EST
1,494			-	119,075	.927	13.1%
1,639 -	3,566		-	110,117	.944	11.7%
1,335 -	3,932 +	9,157	-	169,440	.955	10.7%

RIGHT UPPER ARM Z MOMENT FROM:

BICEPS C FLEXED R	AX ARM C	ACROMIAL- RADIAL L		CONSTANT	R	SE EST
3,468			-	86,144	.947	11.9%
1,986 +	1,613		-	89,749	.967	9.6%
1,935 +	1,201 +	653	-	98,396	.975	8.5%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 11

RIGHT FOREARM

ANTHROPOMETRY
OF SEGMENT   RANGE   MEAN   S.D.
RADIAL-STYLION LGTH
             24.1- 30.9   27.05   1.81
ELBOW BR   6.4-   8.1   7.09   .44
ELBOW CIR 23.1- 31.4   26.57   1.85
MIDFOREARM CIRC
             20.5- 28.4   23.42   1.56
MIDFOREARM BREADTH
             6.1- 10.0   7.95   .67
WRIST CIR 15.3- 19.8   16.99   1.04
WRIST BR   4.9-   6.4   5.54   .37

        RIGHT FOREARM VOLUME
        RANGE   MEAN   S.D.
    1,018 - 2,170   1,396   247
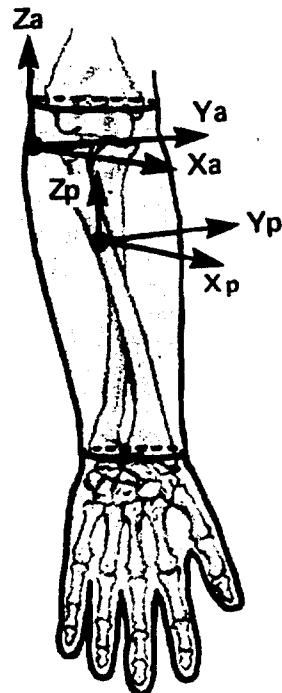
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
                RANGE   MEAN   S.D.
X-AXIS   -2.27   -   .07   -.97   .61
Y-AXIS   2.63   -   4.14   3.22   .33
Z-AXIS -11.86   -   -8.87   -10.37   .76

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
RIGHT OLECRANON	3.52	.50	1.66	.86	-12.89	.83
R MED HUM EPICON	4.41	.77	-1.89	1 07	-11.79	.70
R RADIAL STYLOID	-.97	.61	-3.41	.35	16.51	1.20
R ULNAR STYLOID	-.97	.61	3.22	.33	16.42	1.15
RIGHT RADIALE	-.97	.61	3.22	.33	-10.37	.76

THE PRINCIPAL MOMENTS OF INERTIA
             RANGE   MEAN   S.D.
X-AXIS   47,484 - 150,408   85,854   26,092
Y-AXIS   48,504 - 154,810   87,411   26,639
Z-AXIS   7,544 - 28,153   12,784   4,108

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
        COSINE MATRIX EXPRESSED IN DEGREES
        X   Y   Z
X   7.61   82.48   88.85   STD. DEV. OF ROT. X =   .90
Y   97.48   7.68   91.70   STD. DEV. OF ROT Y =   2.61
Z   91.36   88.46   2.05   STD. DEV. OF ROT Z = 13.32

RIGHT FOREARM: REGRESSION EQUATIONS

RIGHT FOREARM VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	-2.06 +	8.40 +	329	.912	7.5%
X MOMENT	=	905 +	537 -	166,237	.910	13.1%
Y MOMENT	=	867 +	566 -	162,961	.909	13.1%
Z MOMENT	=	-142 +	167 +	9,488	.885	15.5%

RIGHT FOREARM VOLUME FROM:

ELBOW CIR	WRIST CIR	RADIAL - STYLION L		CONSTANT	R	SE EST
126.30			-	1,963.77	.944	5.9%
85.56 +	81.95		-	2,273.27	.959	5.2%
67.38 +	76.39 +	28.10	-	2,453.90	.968	4.7%

RIGHT FOREARM X MOMENT FROM:

RADIAL - STYLION L	WRIST CIR	ELBOW CIR		CONSTANT	R	SE EST
13,043			-	266,304	.907	13.0%
8,557 +	11,249		-	336,437	.964	8.4%
7,476 +	6,807 +	3,694	-	329,986	.970	7.8%

RIGHT FOREARM Y MOMENT FROM:

RADIAL - STYLION L	WRIST CIR	ELBOW CIR		CONSTANT	R	SE EST
13,288			-	271,362	.905	13.2%
8,644 +	11,647		-	343,975	.963	8.5%
7,515 +	7,008 +	3,858	-	337,239	.970	7.8%

RIGHT FOREARM Z MOMENT FROM:

ELBOW CIR	MIDFOREARM CIRC	WRIST BR		CONSTANT	R	SE EST
2,074			-	42,371	.932	11.8%
1,653 +	730		-	48,283	.954	10.0%
1,355 +	782 +	1,953	-	52,297	.962	9.2%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 12

RIGHT HAND

```
ANTHROPOMETRY
OF SEGMENT  RANGE       MEAN    S.D.
HAND LGTH 17.3- 21.7   18.94   1.04
HAND BR    7.8-  9.8    8.64    .49
HAND CIRC 18.7- 23.5   20.87   1.08
META-III-DACTYL LGTH
          9.5- 12.9   10.94    .65


        RIGHT HAND  VOLUME
      RANGE            MEAN      S. D.
   410 -      677      512        69
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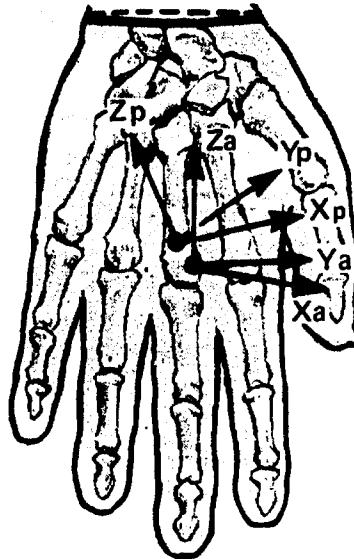
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LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
              RANGE              MEAN      S.D.
X-AXIS   -1.76   -    .03       -.75       .39
Y-AXIS   -1.01   ~    .12       -.46       .28
Z-AXIS     .75   -   1.92       1.31       .32
```

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LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS
                   X-MEAN  X-S.D.  Y-MEAN  Y-S.D.  Z-MEAN  Z-S.D.
R RADIAL STYLOID     .45     .82   -1.77     .43   -6.98     .44
R ULNAR STYLOID     -.90     .87    4 63     .56   -6.33     .53
R METACARPALE V     -.75     .39    5.08     .26    1.31     .32
R METACARPALE II    -.75     .39   -4.21     .26    1.31     .32
RIGHT DACTYLION     -.75     .39    -.99     .77   12.07     .70
```

```
THE PRINCIPAL MOMENTS OF INERTIA
            RANGE              MEAN      S.D.
X-AXIS   8,549 -  20,711     12,821     3,043
Y-AXIS   6,757 -  17,217     10,498     2,504
Z-AXIS   2,759 -   6,678      4,093       956
```

```
PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
        COSINE MATRIX EXPRESSED IN DEGREES
       X        Y        Z
X   13.44    79.13    82.19    STD. DEV. OF ROT. X =   4.12
Y  101.75    13.30    83.85    STD. DEV. OF ROT. Y =   4.21
Z   96.43    97.57     9.96    STD. DEV. OF ROT. Z =   3.36
```

RIGHT HAND: REGRESSION EQUATIONS

RIGHT HAND VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT		CONSTANT	R	SE EST*
VOLUME	=	1.69 +	1.60 -		62	.888	6.4%
X MOMENT	=	133 +	48 -		18,865	.852	12.9%
Y MOMENT	=	124 +	34 -		17,258	.847	13.1%
Z MOMENT	=	12 +	26 -		2,404	.884	11.3%

RIGHT HAND VOLUME FROM:

WEIGHT	HAND CIRC	META-THREE DACTYL L		CONSTANT	R	SE EST
2.12			+	151.11	.883	6.5%
1.18 +	31.16		-	340.70	.930	5.2%
.95 +	24.58 +	30.29 -		494.22	.954	4.3%

RIGHT HAND X MOMENT FROM:

WEIGHT	META-THREE DACTYL L	HAND CIRC		CONSTANT	R	SE EST
88			-	2,133	.834	13.3%
59 +	2,059		-	19,619	.901	10.7%
37 +	1,752 +	852 -		30,452	.918	9.9%

RIGHT HAND Y MOMENT FROM:

HAND LGTH	HAND CIRC		CONSTANT	R	SE EST
2,060		-	28,437	.855	12.6%
1,390 +	1,113	-	39,028	.941	8.3%

RIGHT HAND Z MOMENT FROM:

HAND CIRC	WEIGHT	META-THREE DACTYL L		CONSTANT	R	SE EST
787			-	12,354	.891	10.8%
454 +	16		-	8,045	.935	8.6%
380 +	13 +	340 -		9,771	.951	7.7%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 13

LEFT UPPER ARM

ANTHROPOMETRY

OF SEGMENT RANGE		MEAN	S.D.
AX ARM C	26.8- 39.5	31.91	2.62
BICEPS C RELAXED L			
	26.0- 37.9	29.85	2.49
BICEPS C FLEXED L			
	27.8- 40.8	31.93	2.55
ACROMIAL-RADIAL LGTH			
	28.3- 37.1	33.39	2.46
ELBOW CIR	23.1- 31.4	26.57	1.85
BICEPS DP -RELAXED			
	9.3- 14.5	10.83	1.14
ELBW BR L	6.3- 8.0	7.05	.43
BICEPS SF	2.0- 10.0	3.74	1.74
TRICEP SF	5.0- 16.5	9.44	2.60
AX ARM DP	9.6- 16.3	12.49	1.25

LEFT UPPER ARM VOLUME

RANGE	MEAN	S.D.
1,259 - 3,142	1,918	387
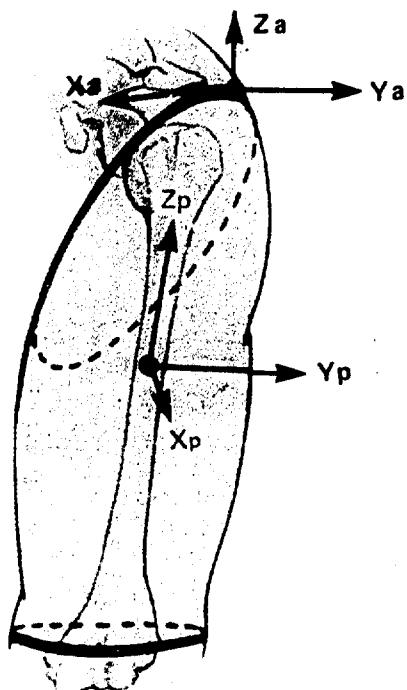
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	.97 -	2.58	1.69	.31
Y-AXIS	-4.36 -	-1.80	-2.96	.41
Z-AXIS	-20.64 -	-14.32	-17.26	1.48

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
LEFT ACROMIALE	1.69	.31	-2.96	.41	-17.26	1.48
LEFT OLECRANON	4.01	.41	2.04	.62	13.48	1.03
L MED HUM EPICON	1.69	.31	5.02	.67	14.00	.95
L LAT HUM EPICON	1.69	.31	-2.96	.41	14.31	1.07
LEFT RADIALE	1.95	.63	-2.52	.45	15.85	1.02

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE	MEAN	S.D.
X-AXIS	59,653 - 260,924	122,994	42,716
Y-AXIS	63,336 - 284,018	129,924	46,288
Z-AXIS	12,028 - 58,303	24,785	9,237

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z	
X	41.50	48.82	94.25	STD. DEV. OF ROT. X = 1.30
Y	131.49	42.05	95.62	STD. DEV. OF ROT. Y = 1.89
Z	90.54	82.97	7.05	STD. DEV. OF ROT. Z = 11.14

LEFT UPPER ARM: REGRESSION EQUATIONS

LEFT UPPER ARM VOLUME AND MOMENTS FROM STATURE AND WEIGHT

	STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME =	-8.09 +	14.66 +	856	.918	8.3%
X MOMENT =	279 +	1,251 -	139,781	.905	15.3%
Y MOMENT =	-15 +	1,454 -	115,179	.906	15.6%
Z MOMENT =	-432 +	408 +	31,947	.888	17.7%

LEFT UPPER ARM VOLUME FROM:

BICEPS C RELAXED L	ACROMIAL- RADIAL L	AX ARM C	CONSTANT	R	SE EST
145.18		-	2,408.15	.936	7.2%
114.02 +	53.00	-	3,249.82	.975	4.7%
81.99 +	43.63 +	40.01 -	3,258.72	.981	4.1%

LEFT UPPER ARM X MOMENT FROM:

WEIGHT	BICEPS C FLEXED L	ACROMIAL- RADIAL L	CONSTANT	R	SE EST
1,336		-	104,640	.905	15.0%
915 +	5,960	-	223,117	.930	13.3%
242 +	8,054 +	7,191 -	415,301	.950	11.4%

LEFT UPPER ARM Y MOMENT FROM:

WEIGHT	BICEPS C FLEXED L	ACROMIAL- RADIAL L	CONSTANT	R	SE EST
1,449		-	117,028	.906	15.4%
946 +	7,133	-	258,828	.936	13.0%
288 +	9,180 +	7,028 -	446,640	.953	11.4%

LEFT UPPER ARM Z MOMENT FROM:

BICEPS C RELAXED L	AX ARM C	ACROMIAL- RADIAL L	CONSTANT	R	SE EST
3,565		-	81,445	.962	10.4%
2,562 +	1,069	-	85,655	.972	9.1%
2,572 +	807 +	401 -	90,996	.975	8.8%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 14

LEFT FOREARM

ANTHROPOMETRY
OF SEGMENT	RANGE	MEAN	S.D.
RADIAL-STYLION LGTH	24.1- 30.9	27.05	1.81
ELBOW BR L	6.3- 8.0	7.05	.43
ELBOW CIR	23.1- 31.4	26.57	1.85
MIDFOREARM CIRC	20.5- 28.4	23.42	1.56
MIDFOREARM BREADTH	6.1- 10.0	7.95	.67
WRIST CIR	15.3- 19.8	16.99	1.04
WRIST BR	4.9- 6.4	5.54	.37

LEFT FOREARM VOLUME
RANGE	MEAN	S.D.
971 - 1,951	1,335	224
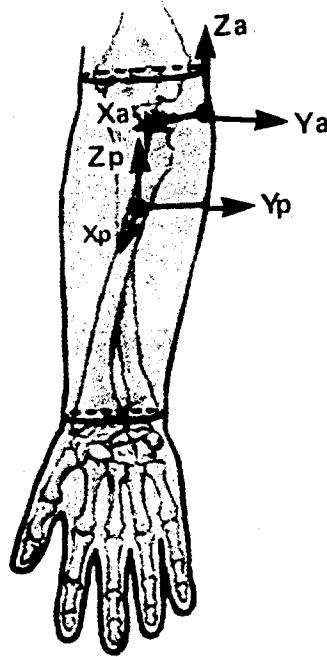
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
	RANGE	MEAN	S.D.
X-AXIS	-2.41 - .13	-.88	.67
Y-AXIS	-4.13 - -2.45	-3.30	.34
Z-AXIS	-12.02 - -9.08	-10.31	.75

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS
	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
LEFT OLECRANON	3.47	.54	-1.49	.95	-12.99	.80
L MED HUM EPICON	4.28	.76	2.05	1.15	-11.87	.93
L RADIAL STYLOID	-.88	.67	3.32	.47	16.32	1.08
L ULNAR STYLOID	-.88	.67	-3.30	.34	16.11	1.23
LEFT RADIALE	-.88	.67	-3.30	.34	-10.31	.75

THE PRINCIPAL MOMENTS OF INERTIA
	RANGE	MEAN	S.D.
X-AXIS	46,540 - 126,191	81,918	22,822
Y-AXIS	47,918 - 131,353	84,184	23,538
Z-AXIS	6,868 - 24,006	11,773	3,587

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES
	X	Y	Z	
X	20.80	69 29	88.10	STD. DEV. OF ROT. X = 1.73
Y	110.75	20 77	89.09	STD. DEV. OF ROT. Y = 2.14
Z	91.46	91 52	2.11	STD. DEV. OF ROT. Z = 13.26

LEFT FOREARM: REGRESSION EQUATIONS

LEFT FOREARM VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	-.93 +	7.30 +	257	.905	7.4%
X MOMENT	=	938 +	431 -	158,022	.921	11.2%
Y MOMENT	=	891 +	470 -	154,021	.922	11.2%
Z MOMENT	=	-105 +	140 +	6,431	.884	14.7%

LEFT FOREARM VOLUME FROM:

ELBOW CIR	WEIGHT	MIDFOREARM CIRC	CONSTANT	R	SE EST
110.60		-	1,606.56	.911	7.0%
61.51 +	3.50	-	896.61	.933	6.3%
37.24 +	3.73 +	36.42 -	1,143.53	.951	5.5%

LEFT FOREARM X MOMENT FROM:

WEIGHT	ELBW BR L	RADIAL - STYLION L	CONSTANT	R	SE EST
715		-	39,973	.907	11.9%
479 +	21,590	-	150,848	.947	9.2%
339 +	16,239 +	3,917 -	195,325	.963	7.9%

LEFT FOREARM Y MOMENT FROM:

WEIGHT	ELBW BR L	RADIAL - STYLION L	CONSTANT	R	SE EST
740		-	41,884	.909	11.8%
496 +	22,258	-	156,190	.950	9.1%
359 +	17,015 +	3,838 -	199,778	.964	7.9%

LEFT FOREARM Z MOMENT FROM:

ELBOW CIR	MIDFOREARM CIRC	WEIGHT	CONSTANT	R	SE EST
1,758		-	34,987	.905	13.2%
1,368 +	677	-	40,467	.930	11.6%
708 +	715 +	46 -	31,531	.944	10.6%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 15

LEFT HAND

```
ANTHROPOMETRY
OF SEGMENT  RANGE      MEAN   S.D.
HAND LGTH 17.3- 21.7  18.94  1.04
HAND BR    7.8-  9.8   8.64   .49
HAND CIRC 18.7- 23.5  20.87  1.08
META-III-DACTYL LGTH
          9.5- 12.9  10.94   .65
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        LEFT HAND VOLUME
     RANGE          MEAN      S.D.
   414 -    678      512       65
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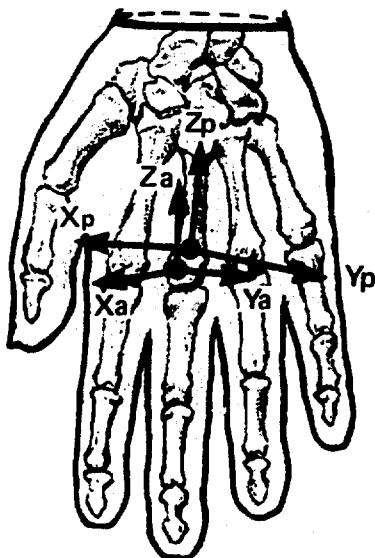
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE			MEAN	S.D.
X-AXIS	-2.23	-	-.22	-.91	.45
Y-AXIS	-.09	-	.90	.45	.26
Z-AXIS	.14	-	2.04	1.14	.39

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
L RADIAL STYLOID	.44	.80	1.77	.43	-6.96	.49
L ULNAR STYLOID	-1.14	.85	-4.58	.52	-6.32	.69
L METACARPALE V	-.91	.45	-5.00	.29	1.14	.39
L METACARPALE II	-.91	.45	4.19	.31	1.14	.39
LEFT DACTYLION	-.91	.45	1.15	.73	12.11	.74

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE			MEAN	S.D.
X-AXIS	8,994	-	22,850	12,909	3,096
Y-AXIS	7,420	-	19,157	10,604	2,589
Z-AXIS	2,816	-	6,090	4,051	883

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
        COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z	
X	17.08	105.20	82.41	STD. DEV. OF ROT. X = 3.14
Y	73.96	17.17	95.94	STD. DEV. OF ROT. Y = 4.79
Z	95.69	82.21	9.66	STD. DEV. OF ROT. Z = 3.94

LEFT HAND: REGRESSION EQUATIONS

LEFT HAND VOLUME AND MOMENTS FROM STATURE AND WEIGHT

	STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME =	2.18 +	1.23 -	83	.845	7.1%
X MOMENT =	181 +	27 -	23,856	.802	14.8%
Y MOMENT =	167 +	17 -	21,834	.795	15.3%
Z MOMENT =	22 +	19 -	3,028	.837	12.3%

LEFT HAND VOLUME FROM

WEIGHT	META-THREE DACTYL L	HAND CIRC		CONSTANT	R	SE EST
1.89			+	190.47	.834	7.2%
1.18 +	50.26		-	236.34	.919	5.2%
.76 +	44.26 +	16.61	-	447.67	.933	4.9%

LEFT HAND X MOMENT FROM:

HAND LGTH	HAND CIRC	META-THREE DACTYL L		CONSTANT	R	SE EST
2,531			-	34,935	.850	12.8%
1,878 +	1,084		-	45,250	.905	10.6%
1,341 +	871 +	1,345	-	45,301	.919	10.0%

LEFT HAND Y MOMENT FROM:

HAND LGTH	HAND CIRC	META-THREE DACTYL L		CONSTANT	R	SE EST
2,139			-	29,817	.859	12.7%
1,663 +	789		-	37,326	.900	11.0%
1,177 +	597 +	1,217	-	37,372	.916	10.3%

LEFT HAND Z MOMENT FROM:

HAND CIRC	META-THREE DACTYL L	WEIGHT		CONSTANT	R	SE EST
715			-	10,886	.877	10.7%
518 +	518		-	12,421	.925	8.6%
382 +	449 +	8	-	10,123	.936	8.1%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 16

RIGHT FLAP

```
ANTHROPOMETRY
OF SEGMENT  RANGE      MEAN    S.D.
THIGH FLAP LENGTH
          15.2- 21.9   18.28   1.62
BUTTOCK C 84.1-109.0   95.29   6.39
BUTT'K DP 20.6- 29.1   24.08   2.08
BISPIN BR 16.8- 27.0   22.29   2.17
HIP BR    30.0- 40.8   34.62   2.33
UPPER THIGH CIRC
          49.9- 65.7   57.02   3.97


       RIGHT FLAP VOLUME
     RANGE          MEAN      S.D.
  2,385 -  4,967   3,440      673
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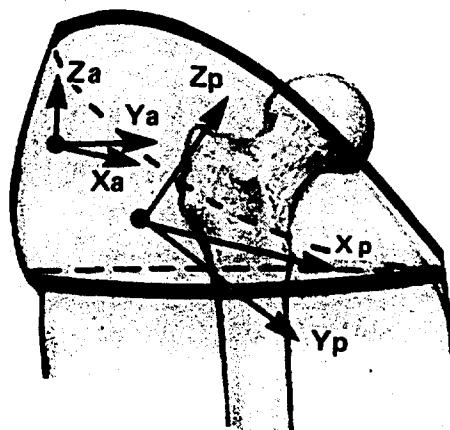


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LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
              RANGE            MEAN      S.D.
X-AXIS   -3.24   -   1.70     -.22      1.12
Y-AXIS    5.67   -   7.37      6.40      .48
Z-AXIS   -9.64   -  -6.04     -7.54     1.00
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LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS
                   X-MEAN  X-S.D.  Y-MEAN  Y-S.D.   Z-MEAN  Z-S.D.
R TROCHANTERION     -.22    1.12    6.40     .48    -7.54    1.00
RIGHT ASIS          -8.33   1.03    -.51    1.27   -13.31    1.25
R GLUTEAL FURROW     8.51    .85    -2.28   1.60     6.51     .63
SCROTALE             3.57   1.68   -10.03   1.06     4.54    1.09
SYMPHYSION         -10.49   2.13   -11.54   1.56    -4.96    1.02
```

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THE PRINCIPAL MOMENTS OF INERTIA
            RANGE                MEAN       S.D.
X-AXIS   64,941 - 214,974      119,598    40,266
Y-AXIS   82,409 - 277,713      154,832    49,483
Z-AXIS  109,565 - 358,229      202,044    64,923
```

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PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
        COSINE MATRIX EXPRESSED IN DEGREES
      X        Y        Z
X    7.94    82.23    91.60     STD. DEV. OF ROT. X =   4.89
Y   96.72    44.37   133.58     STD. DEV. OF ROT. Y =   6.63
Z   94.20    46.68    43.63     STD. DEV. OF ROT. Z =   8.75
```

RIGHT FLAP: REGRESSION EQUATIONS

RIGHT FLAP VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	-23.15 +	27.48 +	2,867	.890	9.2%
X MOMENT	=	-1,201 +	1,590 +	61,862	.889	16.0%
Y MOMENT	=	-1,924 +	2,113 +	136,174	.908	13.8%
Z MOMENT	=	-2,261 +	2,738 +	136,854	.925	12.6%

RIGHT FLAP VOLUME FROM:

BUTTOCK C	THIGH FLAP LENGTH	UPPER THIGH CIRC	CONSTANT	R	SE EST
95.98		-	5,706.73	.911	8.2%
77.96 +	130.87	-	6,384.79	.948	6.4%
47.57 +	132.36 +	51.92 -	6,475.07	.95	6.2%

RIGHT FLAP X MOMENT FROM:

BUTTOCK C	THIGH FLAP LENGTH	WEIGHT	CONSTANT	R	SE EST
5,690		-	422,657	.903	14.7%
4,554 +	8,255	-	465,426	.945	11.4%
2,554 +	8,487 +	462 -	357,800	.952	10.9%

RIGHT FLAP Y MOMENT FROM:

BUTTOCK C	THIGH FLAP LENGTH	BUTT'K DP	CONSTANT	R	SE EST
7,123		-	523,965	.920	12.8%
6,156 +	7,026	-	560,369	.940	11.3%
4,102 +	8,691 +	6,647 -	555,366	.951	10.4%

RIGHT FLAP Z MOMENT FROM:

BUTTOCK C	THIGH FLAP LENGTH	UPPER THIGH CIRC	CONSTANT	R	SE EST
9,522		-	705,396	.937	11.4%
8,372 +	8,355	-	748,683	.953	10.0%
5,187 +	8,511 +	5,442 -	758,144	.961	9.4%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 17

RIGHT THIGH MINUS FLAP

ANTHROPOMETRY

OF SEGMENT	RANGE	MEAN	S.D.
THIGH L	41.4- 53.1	46.55	3.42
BUTTOCK C	84.1-109.0	95.29	6.39
BUTT'K DP	20.6- 29.1	24.08	2.08
UPPER THIGH CIRC			
	49.9- 65.7	57.02	3.97
MIDTHIGH CIRC			
	47.8- 60.1	52.90	3.01
MIDTHIGH DEPTH			
	15.9- 19.7	17.40	1.00
KNEE CIRC	33.5- 43.1	37.41	2.50

RIGHT THIGH MINUS FLAP VOLUME

RANGE	MEAN	S.D.
4,928 - 8,903	6,444	1,110
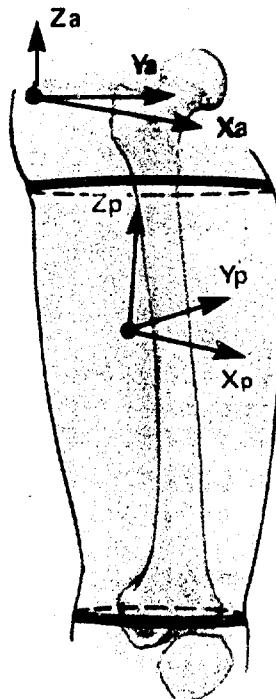
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	-.91	- 2.36	.86	.75
Y-AXIS	5.79	- 8.38	6.87	.54
Z-AXIS	-30.92	- -23.33	-26.56	2.09

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
R TROCHANTERION	.86	.75	6.87	.54	-26.56	2.09
R LAT FEM CONDYL	.86	.75	6.87	.54	17.55	1.52
R MED FEM CONDYL	.86	.75	-4.47	.52	18.73	1.59
RIGHT TIBIALE	-.39	.97	-2.87	.62	20.98	1.54
RIGHT FIBULARE	-.22	1.37	6.35	.71	20.13	1.64

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE		MEAN	S.D.
X-AXIS	345,474 -	999,616	603,733	193,349
Y-AXIS	361,418 -	1,020,188	622,730	197,547
Z-AXIS	145,950 -	401,339	232,604	65,646

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z		
X	12.04	79.48	95.78	STD. DEV. OF ROT. X =	1.44
Y	100.74	10.87	91.66	STD. DEV. OF ROT. Y =	2.51
Z	84.63	87.30	6.02	STD. DEV. OF ROT. Z =	14.17

RIGHT THIGH MINUS FLAP: REGRESSION EQUATIONS

RIGHT THIGH MINUS FLAP VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT		CONSTANT	R	SE EST*
VOLUME	=	58.34 +	17.83 -		6,949	.949	5.6%
X MOMENT	=	15,627 +	1,108 -	2,358,876	.931	12.1%
Y MOMENT	=	16,044 +	1,121 -	2,416,120	.934	11.8%
Z MOMENT	=	1,013 +	1,834 -	259,580	.945	9.5%

RIGHT THIGH MINUS FLAP VOLUME FROM:

STATURE	MDTHIGH C	THIGH LGTH	CONSTANT	R	SE EST
107.10		-	12,565.68	.929	6.5%
69.11 +	156.19	-	14,086.59	.966	4.6%
46.66 +	156.99 +	69.99 -	13,397.57	.971	4.3%

RIGHT THIGH MINUS FLAP X MOMENT FROM:

STATURE	THIGH LGTH	MDTHIGH C	CONSTANT	R	SE EST
18,658		-	2,707,982	.929	12.1%
11,919 +	21,188	-	2,497,060	.944	11.0%
7,738 +	21,481 +	16,808 -	2,657,796	.958	9.7%

RIGHT THIGH MINUS FLAP Y MOMENT FROM:

STATURE	THIGH LGTH	MDTHIGH C	CONSTANT	R	SE EST
19,110		-	2,769,242	.931	11.8%
12,236 +	21,454	-	2,555,672	.946	10.7%
8,257 +	21,737 +	16,200 -	2,710,598	.958	9.6%

RIGHT THIGH MINUS FLAP Z MOMENT FROM:

WEIGHT	MDTHIGH C	STATURE	CONSTANT	R	SE EST
2,140		-	132,107	.943	9.5%
1,265 +	9,661	-	494,084	.968	7.4%
857 +	9,908 +	1,275 -	663,819	.971	7.1%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 18

RIGHT CALF

ANTHROPOMETRY

OF SEGMENT	RANGE		MEAN	S.D.
CALF LGTH	34.3-	47.4	40.74	3.05
CALF CIRC	35.0-	42.7	37.95	2.08
ANKLE CIR	19.6-	25.1	22.43	1.29
KNEE CIRC	33.5-	43.1	37.41	2.50
ANKLE BR	5.1-	6.6	5.90	.43
KNEE BR	8.6-	10.9	9.64	.57
CALF DP	11.0-	13.7	12.02	.69

RIGHT CALF VOLUME

RANGE		MEAN	S.D.
2,869 -	5,212	3,848	629
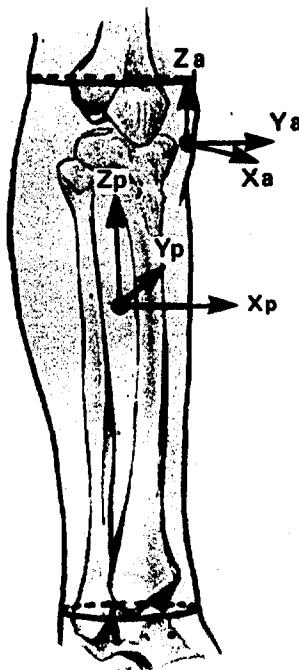
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	-2.87	- -.11	-1.25	.68
Y-AXIS	-6.49	- -4.85	-5.76	.40
Z-AXIS	-18.47	- -12.02	-15.15	1.51

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
RIGHT SPHYRION	-1.25	.68	-5.76	.40	25.53	1.92
RIGHT TIBIALE	-1.25	.68	-5.76	.40	-15.15	1.51
RIGHT FIBULARE	-4.34	.96	2.89	.86	-15.31	1.27
R MED MALLEOLUS	-.89	.81	-5.87	.49	23.73	1.89
R LAT MALLEOLUS	-1.25	.68	1.97	.37	25.61	2.04

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE		MEAN	S.D.
X-AXIS	341,549 -	967,680	570,096	175,026
Y-AXIS	346,305 -	979,884	578,473	176,883
Z-AXIS	38,846 -	108,162	66,072	17,807

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z					
X	40.74	49.28	88.95	STD. DEV. OF ROT. X =	1.09
Y	130.74	40.75	89.21	STD. DEV. OF ROT. Y =	1.11
Z	90.28	91.28	1.31	STD. DEV. OF ROT. Z =	6.86

RIGHT CALF: REGRESSION EQUATIONS

RIGHT CALF VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	26.72 +	11.84 -	2,912	.933	6.1%
X MOMENT	=	12,323 +	1,702 -	1,907,428	.941	10.7%
Y MOMENT	=	12,429 +	1,730 -	1,922,497	.941	10.7%
Z MOMENT	=	291 +	477 -	66,811	.920	10.9%

RIGHT CALF VOLUME FROM:

WEIGHT	CALF C RT	CALF LGTH		CONSTANT	R	SE EST
19.93			+	451.56	.917	6.6%
11.30 +	150.24		-	3,786.04	.964	4.5%
8.48 +	133.42 +	51.31	-	4,755.85	.980	3.4%

RIGHT CALF X MOMENT FROM:

STATURE	CALF DP	ANKLE CIR		CONSTANT	R	SE EST
16,979			-	2,443,792	.934	11.2%
12,519 +	85,244		-	2,675,111	.961	8.8%
10,851 +	65,309 +	26,079	-	2,723,962	.967	8.2%

RIGHT CALF Y MOMENT FROM:

STATURE	CALF DP	ANKLE CIR		CONSTANT	R	SE EST
17,161			-	2,467,648	.934	11.1%
12,671 +	85,827		-	2,700,549	.961	8.8%
11,005 +	65,921 +	26,041	-	2,749,329	.967	8.2%

RIGHT CALF Z MOMENT FROM:

| CALF C RT	WEIGHT	CALF LGTH		CONSTANT	R	SE EST
8,111			-	242,153	.945	8.9%
5,029 +	276		-	172,074	.983	5.1%
4,830 +	243 +	607	-	183,552	.986	4.8%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 19

RIGHT FOOT

ANTHROPOMETRY

OF SEGMENT	RANGE	MEAN	S.D.
FOOT LGTH	24.2- 31.3	26.61	1.64
FOOT BR	9.3- 11.7	10.49	.59
SPHYRN HT	5.8- 8.7	7.07	.68
ANKLE CIR	19.6- 25.1	22.43	1.29
ARCH CIRC	22.6- 37.5	26.01	2.45
BALL OF FOOT CIRC			
	22.6- 36.6	25.73	2.39

RIGHT FOOT VOLUME

RANGE	MEAN	S.D.
748 - 1,368	976	155
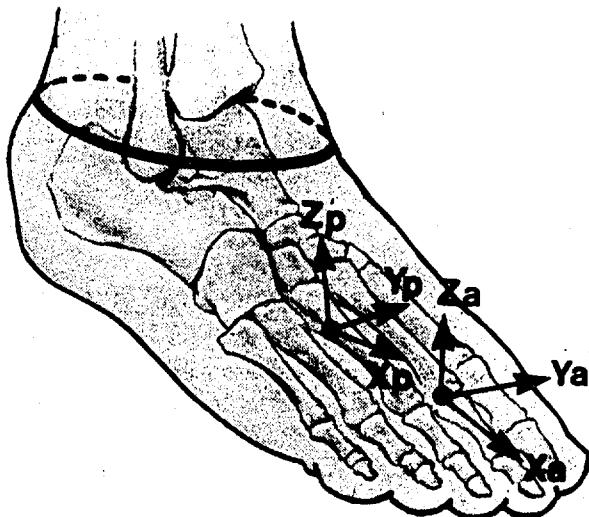
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	-9.60 -	-6.62	-7.79	.69
Y-AXIS	-.81 -	.44	-.14	.35
Z-AXIS	-1.32 -	-.05	-.66	.26

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
RIGHT SPHYRION	5.57	.50	-4.22	.42	-2.17	.53
R METATARSAL V	-5.69	.74	5.73	.36	-.66	.26
R METATARSAL I	-7.79	.69	-4.96	.37	-.66	.26
RIGHT TOE II	-14.94	1.16	-.14	.35	-1.83	.59
R POS CALCANEUS	11.56	.71	-.14	.35	-.66	.26

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE		MEAN	S.D.
X-AXIS	5,160 -	13,363	8,221	2,122
Y-AXIS	26,845 -	83,410	43,056	12,504
Z-AXIS	28,156 -	86,390	45,509	12,911

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z						
X	9.35	85.95	81.04	STD. DEV. OF ROT. X =					7.03
Y	95.18	8.76	82.95	STD. DEV. OF ROT. Y =					2.04
Z	98.35	97.75	11.44	STD. DEV. OF ROT. Z =					1.40

RIGHT FOOT: REGRESSION EQUATIONS

RIGHT FOOT VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE		WEIGHT		CONSTANT	R	SE EST*
VOLUME	=	9.31	+	1.87	-	994	.907	6.9%
X MOMENT	=	110	+	30	-	16,550	.895	11.9%
Y MOMENT	=	948	+	71	-	137,353	.882	14.2%
Z MOMENT	=	954	+	86	-	138,369	.889	13.4%

RIGHT FOOT VOLUME FROM:

STATURE		ANKLE CIR		SPHYRN HT		CONSTANT	R	SE EST
14.42					-	1,582.84	.895	7.2%
8.25	+	59.29			-	1,816.89	.948	5.3%
6.58	+	47.41	+	65.77	-	1,720.30	.972	3.9%

RIGHT FOOT X MOMENT FROM:

ANKLE CIR		SPHYRN HT		STATURE		CONSTANT	R	SE EST
1,471					-	24,734	.893	11.8%
1,054	+	1,269			-	24,404	.948	8.5%
691	+	1,018	+	77	-	28,110	.971	6.5%

RIGHT FOOT Y MOMENT FROM:

FOOT L		SPHYRN HT		ANKLE CIR		CONSTANT	R	SE EST
7,184					-	148,034	.945	9.7%
6,072	+	4,666			-	151,582	.967	7.6%
4,965	+	3,580	+	2,233	-	164,452	.977	6.6%

RIGHT FOOT Z MOMENT FROM:

FOOT L		ANKLE CIR		SPHYRN HT		CONSTANT	R	SE EST
7,446					-	152,559	.948	9.2%
5,426	+	3,303			-	172,814	.970	7.1%
5,149	+	2,627	+	2,896	-	170,875	.978	6.3%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 20

LEFT FLAP

ANTHROPOMETRY

OF SEGMENT	RANGE	MEAN	S.D.
THIGH FLAP LENGTH	15.2- 21.9	18.28	1.62
BUTTOCK C	84.1-109.0	95.29	6.39
BUTT'K DP	20.6- 29.1	24.08	2.08
BISPIN BR	16.8- 27.0	22.29	2.17
HIP BR	30.0- 40.8	34.62	2.33
UPPER THIGH CIRC	49.9- 65.7	57.02	3.97

LEFT FLAP VOLUME

RANGE	MEAN	S.D.
2,479 - 5,019	3,356	655
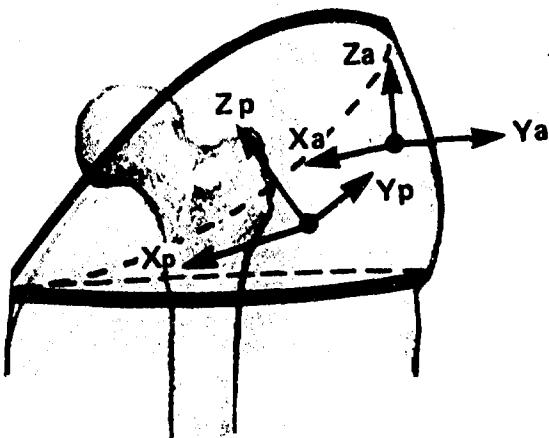
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	-1.56 -	2.42	.27	1.04
Y-AXIS	-8.24 -	-5.18	-6.40	.73
Z-AXIS	-9.99 -	-6.21	-7.82	.92

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
L TROCHANTERION	.27	1.04	-6.40	.73	-7.82	.92
LEFT ASIS	-8.16	1.01	-.56	1.32	-13.20	1.08
L GLUTEAL FURROW	8.87	.81	2.35	1.43	6.43	.61
SCROTALE	2.57	1.76	10.14	1.11	4.53	.80
SYMPHYSION	-11.63	2.23	10.28	1.61	-4.93	1.17

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE	MEAN	S.D.
X-AXIS	69,992 - 221,069	114,720	39,234
Y-AXIS	90,333 - 280,231	151,283	48,207
Z-AXIS	117,336 - 360,795	195,930	61,717

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z	
X	6.27	84.81	86.48	STD. DEV. OF ROT. X = 4.06
Y	96.18	44.22	46.44	STD. DEV. OF ROT. Y = 6.30
Z	88.95	133.75	43.77	STD. DEV. OF ROT. Z = 8.14

LEFT FLAP: REGRESSION EQUATIONS

LEFT FLAP VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	-25.64 +	27.74 +	3,180	.896	9.0%
X MOMENT	=	-1,475 +	1,628 +	99,038	.884	16.5%
Y MOMENT	=	-1,804 +	2,051 +	121,919	.915	13.3%
Z MOMENT	=	-2,166 +	2,611 +	135,447	.927	12.2%

LEFT FLAP VOLUME FROM

BUTTOCK C	THIGH FLAP LENGTH	BISPIN BR	CONSTANT	R	SE EST
94.44		-	5,643.72	.921	7.7%
83.03 +	82.87	-	6,073.07	.937	7.0%
95.26 +	86.74 -	63.62 -	5,890.51	.952	6.3%

LEFT FLAP X MOMENT FROM:

HIP BR	THIGH FLAP LENGTH	BUTT'K DP	CONSTANT	R	SE EST
15,312		-	415,068	.910	14.4%
13,348 +	5,075	-	440,008	.926	13.3%
10,898 +	5,477 +	3,795 -	454,036	.938	12.5%

LEFT FLAP Y MOMENT FROM:

BUTTOCK C	BISPIN BR	THIGH FLAP LENGTH	CONSTANT	R	SE EST
6,944		-	510,509	.921	12.7%
7,923 -	4,878	-	494,972	.937	11.5%
7,309 -	5,052 +	4,715 -	518,845	.947	10.8%

LEFT FLAP Z MOMENT FROM:

BUTTOCK C	BISPIN BR	THIGH FLAP LENGTH	CONSTANT	R	SE EST
9,052		-	666,769	.937	11.2%
10,103 -	5,239	-	650,082	.949	10.3%
9,407 -	5,437 +	5,345 -	677,146	.956	9.7%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 21

LEFT THIGH MINUS FLAP

```
ANTHROPOMETRY
OF SEGMENT   RANGE        MEAN    S.D.
THIGH L    41.4- 53.1    46.55   3.42
BUTTOCK C 84.1-109.0     95.29   6.39
BUTT'K DP 20.6- 29.1     24.08   2.08
UPPER THIGH CIRC
           49.9- 65.7    57.02   3.97
MIDTHIGH CIRC
           47.8- 60.1    52.90   3.01
MIDTHIGH DEPTH
           15.9- 19.7    17.40   1.00
KNEE CIRC 33.5- 43.1     37.41   2.50


   LEFT THIGH MINUS FLAP VOLUME
        RANGE          MEAN     S.D.
   4,720 - 8,896      6,289    1,096
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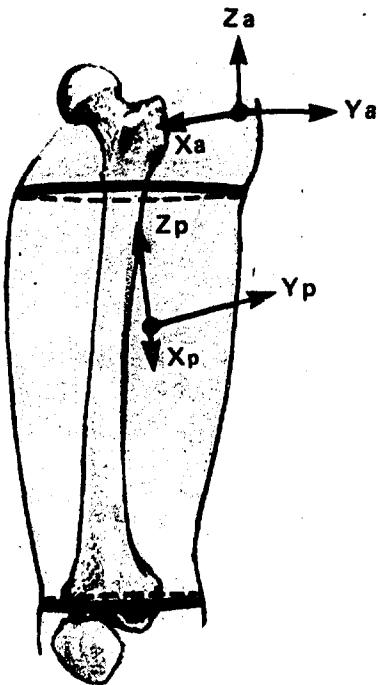

LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE			MEAN	S.D.
X-AXIS	-.04	-	2.22	.94	.59
Y-AXIS	-7.93	-	-5.28	-6.53	.61
Z-AXIS	-31.18	-	-23.61	-26.68	1.88

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
L TROCHANTERION	.94	.59	-6.53	.61	-26.68	1.88
L LAT FEM CONDYL	.94	.59	-6.53	.61	17.33	1.34
L MED FEM CONDYL	.94	.59	4.75	.46	19.31	1.45
LEFT TIBIALE	-.25	1.10	2.95	.84	21.53	1.46
LEFT FIBULARE	.09	.93	-6.34	.76	20.20	1.55

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE			MEAN	S.D.
X-AXIS	320,299	-	1,006,732	574,638	180,235
Y-AXIS	333,853	-	1,061,071	604,723	188,113
Z-AXIS	132,397	-	397,493	224,983	65,342

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z	
X	29.05	61.27	93.94	STD. DEV. OF ROT. X = 1.72
Y	118.37	28.83	85.30	STD. DEV. OF ROT. Y = 2.35
Z	84.29	92.24	6.14	STD. DEV. OF ROT. Z = 11.17

LEFT THIGH MINUS FLAP: REGRESSION EQUATIONS

LEFT THIGH MINUS FLAP VOLUME AND MOMENTS FROM STATURE AND WEIGHT

	STATURE	WEIGHT		CONSTANT	R	SE EST*
VOLUME =	51.91 +	18.69 -		6,110	.928	6.7%
X MOMENT =	13,654 +	1,223 -		2,057,227	.912	13.4%
Y MOMENT =	14,059 +	1,361 -		2,122,558	.914	13.1%
Z MOMENT =	996 +	1,780 -		255,005	.923	11.5%

LEFT THIGH MINUS FLAP VOLUME FROM:

WEIGHT	MDTHIGH C	STATURE		CONSTANT	R	SE EST
34.42			+	424.18	.908	7.4%
20.34 +	155.44		-	5,399.70	.932	6.5%
2.29 +	166.36 +	56.31 -		12,897.46	.954	5.5%

LEFT THIGH MINUS FLAP X MOMENT FROM:

STATURE	MDTHIGH C	THIGH LGTH		CONSTANT	R	SE EST
16,998			-	2,442,457	.908	13.4%
12,159 +	19,899		-	2,636,222	.931	11.8%
8,582 +	20,026 +	11,148 -		2,526,483	.936	11.6%

LEFT THIGH MINUS FLAP Y MOMENT FROM:

STATURE	MDTHIGH C	THIGH LGTH		CONSTANT	R	SE EST
17,781			-	2,551,381	.910	13.1%
12,566 +	21,444		-	2,760,187	.935	11.4%
8,954 +	21,572 +	11,259 -		2,649,357	.939	11.2%

LEFT THIGH MINUS FLAP Z MOMENT FROM:

WEIGHT	MDTHIGH C	STATURE		CONSTANT	R	SE EST
2,081			-	129,645	.921	11.5%
1,136 +	10,435		-	520,616	.951	9.3%
726 +	10,683 +	1,278 -		690,845	.954	9.2%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 22

LEFT CALF

ANTHROPOMETRY

OF SEGMENT	RANGE		MEAN	S.D.
CALF LGTH	34.3-	47.4	40.74	3.05
CALF C LF	24.6-	43.1	37.42	3.21
ANKLE CIR	19.6-	25.1	22.43	1.29
KNEE CIRC	33.5-	43.1	37.41	2.50
ANKLE BR	5.1-	6.6	5.90	.43
KNEE BR L	8.5-	11.1	9.57	.58
CALF DP	11.0-	13.7	12.02	.69

LEFT CALF VOLUME

RANGE		MEAN	S.D.
2,788 -	5,239	3,842	670
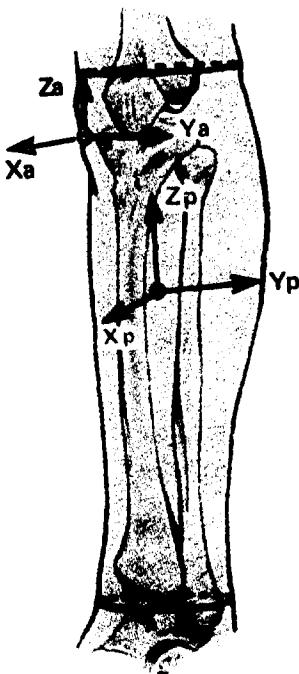
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	-3.98	- .68	-1.13	.91
Y-AXIS	3.26	- 6.83	5.64	.58
Z-AXIS	-17.78	- -12.31	-14.65	1.44

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
LEFT SPHYRION	-1.13	.91	5.64	.58	25.75	2.01
LEFT TIBIALE	-1.13	.91	5.64	.58	-14.65	1.44
LEFT FIBULARE	-4.55	.91	-3.00	1.00	-15.14	1.36
L MED MALLEOLUS	-.92	.87	5.67	.57	23.80	2.01
L LAT MALLEOLUS	-.97	.81	-1.95	.33	25.88	2.07

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE		MEAN	S.D.
X-AXIS	337,925 -	1,020,043	580,501	184,925
Y-AXIS	344,001 -	1,039,896	589,841	187,723
Z-AXIS	37,375 -	112,646	66,419	19,681

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z		
X	7.46	97.46	89.83	STD. DEV. OF ROT. X =	.73
Y	82.54	7.62	91.54	STD. DEV. OF ROT. Y =	1.48
Z	89.97	88.45	1.55	STD. DEV. OF ROT. Z =	10.47

LEFT CALF: REGRESSION EQUATIONS

LEFT CALF VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	30.50 +	11.88 -	3,596	.930	6.6%
X MOMENT	=	14,369 +	1,352 -	2,200,471	.945	10.8%
Y MOMENT	=	14,600 +	1,366 -	2,234,460	.944	10.8%
Z MOMENT	=	346 +	512 -	82,292	.910	12.7%

LEFT CALF VOLUME FROM

WEIGHT	ANKLE CIR	CALF LGTH		CONSTANT	R	SE EST
21.12			+	243.84	.912	7.3%
13.94 +	201.19		-	3,039.35	.941	6.1%
11.36 +	166.59 +	51.72	-	3,930.21	.955	5.4%

LEFT CALF X MOMENT FROM:

STATURE	CALF DP	CALF LGTH		CONSTANT	R	SE EST
18,068			-	2,626,569	.941	11.0%
13,745 +	82,628		-	2,850,791	.963	8.9%
10,693 +	83,844 +	10,801	-	2,761,441	.967	8.5%

LEFT CALF Y MOMENT FROM:

STATURE	CALF DP	CALF LGTH		CONSTANT	R	SE EST
18,337			-	2,665,012	.940	11.0%
13,917 +	84,489		-	2,894,285	.963	8.8%
10,754 +	85,745 +	11,155	-	2,802,009	.967	8.5%

LEFT CALF Z MOMENT FROM:

WEIGHT	CALF DP	CALF C LF		CONSTANT	R	SE EST
617			-	38,708	.907	12.7%
361 +	13,253		-	154,207	.946	10.0%
238 +	10,638 +	1,416	-	165,043	.957	9.0%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 23

LEFT FOOT

```
ANTHROPOMETRY
OF SEGMENT  RANGE       MEAN   S.D.
FOOT LGTH 24.2- 31.3    26.61  1.64
FOOT BR    9.3- 11.7    10.49   .59
SPHYRN HT  5.8-  8.7     7.07   .68
ANKLE CIR 19.6- 25.1    22.43  1.29
ARCH CIRC 22.6- 37.5    26.01  2.45
BALL OF FOOT CIRC
          22.6- 36.6    25.73  2.39

        LEFT FOOT VOLUME
     RANGE          MEAN    S.D.
    700 - 1,333      952     161
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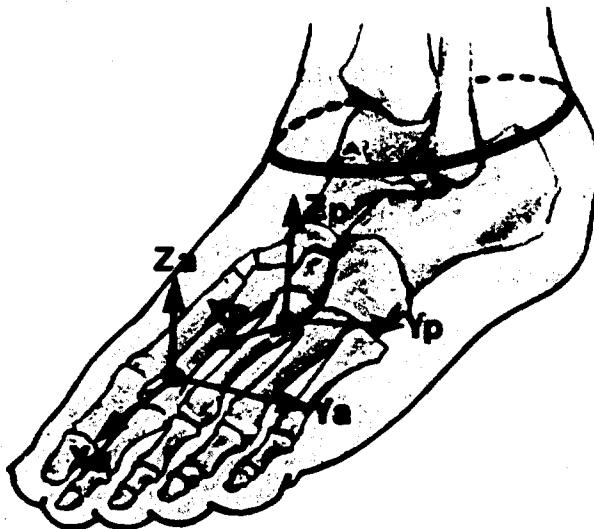
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	-9.49	-6.47	-7.60	.70
Y-AXIS	-.49	.88	.01	.31
Z-AXIS	-.96	-.11	-.57	.23

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
LEFT SPHYRION	5.84	.63	4.22	.50	-2.06	.49
L METATARSAL V	-5.52	.63	-5.77	.38	-.57	.23
L METATARSAL I	-7.60	.70	4.77	.34	-.57	.23
LEFT TOE II	-14.68	1.13	.01	.31	-1.69	.58
L POS CALCANEUS	11.59	.74	.01	.31	-.57	.23

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE		MEAN	S.D.
X-AXIS	4,666	12,497	7,756	2,162
Y-AXIS	25,344	80,854	41,654	12,514
Z-AXIS	26,601	83,364	43,753	12,870

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z	
X	8.97	92.17	81.30	STD. DEV. OF ROT. X = 7.49
Y	87.21	4.83	93.94	STD. DEV. OF ROT. Y = 1.83
Z	98.52	85.69	9.56	STD. DEV. OF ROT. Z = 1.38

LEFT FOOT: REGRESSION EQUATIONS

LEFT FOOT VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	8.37 +	2.32 −	930	.897	7.7%
X MOMENT	=	100 +	34 −	15,824	.878	13.8%
Y MOMENT	=	851 +	101 −	126,715	.873	15.2%
Z MOMENT	=	838 +	118 −	125,144	.876	14.7%

LEFT FOOT VOLUME FROM

ANKLE CIR	STATURE	SPHYRN HT		CONSTANT	R	SE EST
114.23			−	1,606.99	.914	7.0%
72.61 +	7.17		−	1,947.15	.953	5.3%
65.11 +	6.11 +	41.49	−	1,886.22	.963	4.8%

LEFT FOOT X MOMENT FROM:

ANKLE CIR	STATURE	SPHYRN HT		CONSTANT	R	SE EST
1,557			−	27,121	.928	10.6%
1,104 +	78		−	30,821	.953	8.8%
1,000 +	63 +	578	−	29,972	.963	8.0%

LEFT FOOT Y MOMENT FROM:

FOOT LGTH	ANKLE CIR	WEIGHT		CONSTANT	R	SE EST
7,083			−	146,761	.931	11.2%
4,870 +	3,619		−	168,955	.959	8.8%
4,475 +	2,686 +	74	−	150,104	.964	8.4%

LEFT FOOT Z MOMENT FROM:

| FOOT LGTH	ANKLE CIR	WEIGHT		CONSTANT	R	SE EST
7,291			−	150,195	.932	10.9%
4,963 +	3,807		−	173,542	.962	8.4%
4,529 +	2,782 +	81	−	152,824	.967	7.9%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 24

RIGHT FOREARM PLUS HAND

```
ANTHROPOMETRY
OF SEGMENT   RANGE      MEAN    S.D.
ELBOW CIR 23.1- 31.4    26.57   1.85
MIDFOREARM CIRC
          20.5- 28.4    23.42   1.56
MIDFOREARM BREADTH
           6.1- 10.0     7.95    .67
WRIST CIR 15.3- 19.8    16.99   1.04
HAND LGTH 17.3- 21.7    18.94   1.04
HAND BR    7.8-  9.8     8.64    .49
HAND CIRC 18.7- 23.5    20.87   1.08
FOREARM-HAND LGTH
          41.6- 52.6    45.98   2.72
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     RIGHT FOREARM PLUS HAND VOLUME
          RANGE          MEAN      S.D.
     1,429 -  2,847     1,907       312
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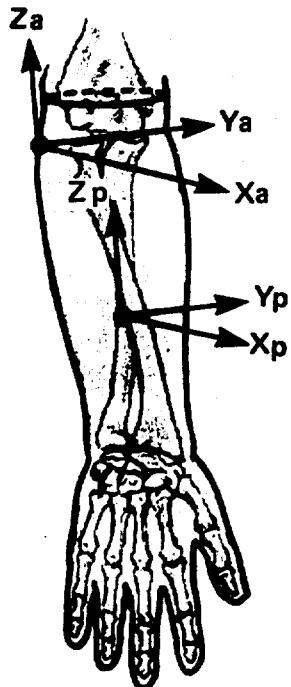
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE			MEAN	S.D.
X-AXIS	-1.97	-	-.35	-1.00	.41
Y-AXIS	2.83	-	4.51	3.44	.35
Z-AXIS	-19.16	-	-14.98	-16.60	.98

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
RIGHT OLECRANON	3.49	.69	1.87	.84	-19.12	1.10
R RADIAL STYLOID	-1.00	.41	-3.20	.33	10.28	1.03
R ULNAR STYLOID	-1.00	.41	3.44	.35	10.19	.95
RIGHT RADIALE	-1.00	.41	3.44	.35	-16.60	.98
RIGHT DACTYLION	1.21	1.71	-.02	1.73	28.88	1.80

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE			MEAN	S.D.
X-AXIS	186,186	-	509,822	303,670	82,880
Y-AXIS	185,168	-	506,682	302,342	82,535
Z-AXIS	10,661	-	36,501	17,327	5,160

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z	
X	6.06	96.06	90.10	STD. DEV. OF ROT. X = 1.33
Y	83.94	6.21	88.66	STD. DEV. OF ROT. Y = 2.67
Z	90.04	91.35	1.35	STD. DEV. OF ROT. Z = 17.03

RIGHT FOREARM PLUS HAND: REGRESSION EQUATIONS

RIGHT FOREARM + HAND VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	-.36 +	10.01 +	267	.918	6.7%
X MOMENT	=	4,086 +	1,316 -	645,877	.913	11.5%
Y MOMENT	=	4,058 +	1,316 -	642,117	.913	11.5%
Z MOMENT	=	-139 +	200 +	7,973	.892	13.9%

RIGHT FOREARM PLUS HAND VOLUME FROM:

ELBOW CIR	WRIST CIR	RADIAL - STYLION L	CONSTANT	R	SE EST
158.86		-	2,318.30	.941	5.6%
100.95 +	116.49	-	2,758.25	.959	4.8%
73.43 +	108.08 +	42.54 -	3,031.69	.973	4.0%

RIGHT FOREARM PLUS HAND X MOMENT FROM:

FOREARM-HAND LGTH	WRIST CIR	HAND CIRC	CONSTANT	R	SE EST
28,050		-	986,648	.920	10.9%
19,439 +	31,774	-	1,130,677	.963	7.6%
17,987 +	19,561 +	17,373 -	1,219,356	.971	6.9%

RIGHT FOREARM PLUS HAND Y MOMENT FROM:

FOREARM-HAND LGTH	WRIST CIR	HAND CIRC	CONSTANT	R	SE EST
27,946		-	983,154	.920	10.9%
19,372 +	31,635	-	1,126,554	.963	7.6%
17,932 +	19,524 +	17,228 -	1,214,491	.971	6.9%

RIGHT FOREARM PLUS HAND Z MOMENT FROM:

| ELBOW CIR	MIDFOREARM CIRC	WEIGHT	CONSTANT	R	SE EST
2,599		-	51,797	.930	11.1%
2,094 +	877	-	58,898	.950	9.6%
1,329 +	921 +	53 -	48,551	.959	8.9%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 25

LEFT FOREARM PLUS HAND

```
ANTHROPOMETRY
OF SEGMENT  RANGE      MEAN   S.D.
ELBOW CIR 23.1- 31.4   26.57  1.85
MIDFOREARM CIRC
          20.5- 28.4   23.42  1.56
MIDFOREARM BREADTH
          6.1- 10.0    7.95    .67
WRIST CIR 15.3- 19.8   16.99  1.04
HAND LGTH 17.3- 21.7   18.94  1.04
HAND BR    7.8-  9.8    8.64    .49
HAND CIRC 18.7- 23.5   20.87  1.08
FOREARM-HAND LGTH
          41.6- 52.6   45.98  2.72
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   LEFT FOREARM PLUS HAND VOLUME
         RANGE          MEAN      S.D.
    1,384 -  2,599     1,847      284
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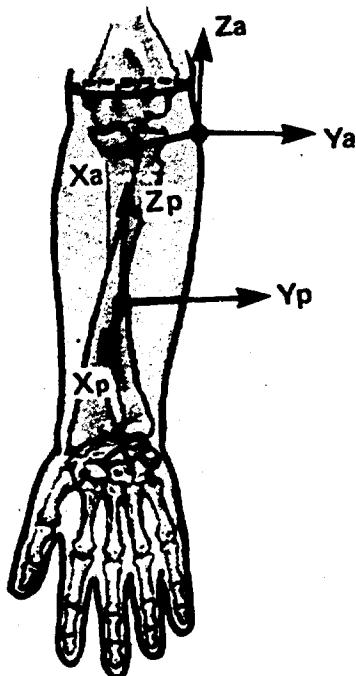
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	-2.21 -	-.01	-.95	.54
Y-AXIS	-4.41 -	-2.81	-3.48	.36
Z-AXIS	-19.62 -	-15.00	-16.67	.96

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
LEFT OLECRANON	3.40	.65	-1.62	1.03	-19.35	1.06
L RADIAL STYLOID	-.95	.54	3.14	.48	9.96	.96
L ULNAR STYLOID	-.95	.54	-3.48	.36	9.75	1.08
LEFT RADIALE	-.95	.54	-3.48	.36	-16.67	.96
LEFT DACTYLION	1.05	1.53	-.14	1.89	28.55	1.79

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE		MEAN	S.D.
X-AXIS	181,313 -	478,092	292,937	75,877
Y-AXIS	180,204 -	474,831	291,156	75,259
Z-AXIS	9,901 -	31,348	16,319	4,542

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
       COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z		
X	32.87	122.87	89.71	STD. DEV. OF ROT. X =	1.45
Y	57.13	32.88	90.79	STD. DEV. OF ROT. Y =	2.38
Z	89.81	89.18	.84	STD. DEV. OF ROT. Z =	15.47

LEFT FOREARM PLUS HAND: REGRESSION EQUATIONS

LEFT FOREARM + HAND VOLUME AND MOMENTS FROM STATURE AND WEIGHT

	STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME =	1.25 +	8.53 +	173	.906	6.7%
X MOMENT =	4,326 +	991 −	643,803	.906	11.3%
Y MOMENT =	4,335 +	970 −	643,567	.907	11.3%
Z MOMENT =	−83 +	164 +	3,136	.887	13.3%

LEFT FOREARM PLUS HAND VOLUME FROM:

WEIGHT	ELBW BR L	MIDFOREARM CIRC	CONSTANT	R	SE EST
8.90		+	330.10	.906	6.6%
6.20 +	247.17	−	939.25	.941	5.4%
5.29 +	202.30 +	44.10 −	1,502.76	.959	4.6%

LEFT FOREARM PLUS HAND X MOMENT FROM:

FOREARM-HAND LGTH	HAND BR	META-III-DACTYL L	CONSTANT	R	SE EST
25,650		−	886,970	.919	10.4%
19,059 +	57,113	−	1,074,944	.961	7.4%
14,724 +	51,181 +	28,026 −	1,129,994	.974	6.2%

LEFT FOREARM PLUS HAND Y MOMENT FROM:

FOREARM-HAND LGTH	HAND BR	META-III-DACTYL L	CONSTANT	R	SE EST
25,468		−	880,366	.920	10.3%
19,019 +	55,882	−	1,064,289	.961	7.4%
14,763 +	50,058 +	27,514 −	1,118,333	.973	6.3%

LEFT FOREARM PLUS HAND Z MOMENT FROM:

ELBOW CIRC	HAND BR	MIDFOREARM CIRC	CONSTANT	R	SE EST
2,230		−	43,010	.907	11.9%
1,625 +	3,055	−	53,184	.933	10.4%
1,387 +	2,652 +	553 −	56,315	.943	9.8%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 26

RIGHT THIGH

ANTHROPOMETRY
OF SEGMENT	RANGE	MEAN	S.D.
THIGH L	41.4- 53.1	46.55	3.42
UPPER THIGH CIRC	49.9- 65.7	57.02	3.97
MDTHIGH C	47.8- 60.1	52.90	3.01
MIDTHIGH DEPTH	15.9- 19.7	17.40	1.00
KNEE CIRC	33.5- 43.1	37.41	2.50
KNEE BR	8.6- 10.9	9.64	.57
GLUT F DP	16.3- 22.7	19.38	1.44

RIGHT THIGH VOLUME
RANGE	MEAN	S.D.
7,365 - 13,604	9,884	1,690
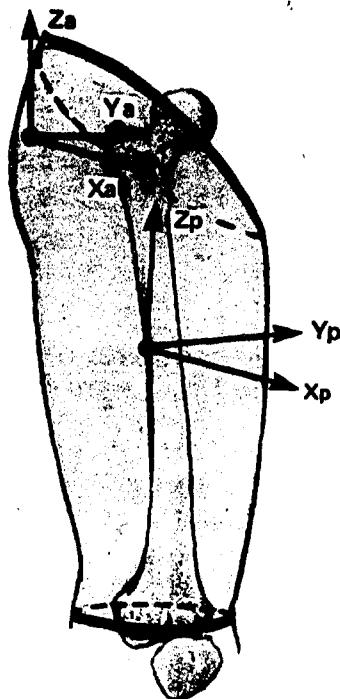
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
	RANGE		MEAN	S.D.
X-AXIS	-1.62 -	2.11	.48	.86
Y-AXIS	5.75 -	8.01	6.71	.48
Z-AXIS	-23.10 -	-17.54	-19.95	1.68

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS
	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
R TROCHANTERION	.48	.86	6.71	.48	-19.95	1.68
R LAT FEM CONDYL	.48	.86	6.71	.48	24.16	1.83
R MED FEM CONDYL	.48	.86	-4.63	.49	25.33	1.96
RIGHT TIBIALE	-.77	1.08	-3.03	.59	27.59	1.86
RIGHT FIBULARE	-.59	1.47	6.18	.69	26.73	1.96

THE PRINCIPAL MOMENTS OF INERTIA
	RANGE	MEAN	S.D.
X-AXIS	869,712 - 2,568,235	1,550,818	475,281
Y-AXIS	913,263 - 2,715,546	1,632,836	496,707
Z-AXIS	257,123 - 721,262	418,835	122,850

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES
	X	Y	Z		
X	9.23	80.81	89.13	STD. DEV. OF ROT. X =	.82
Y	99.20	9.27	88.90	STD. DEV. OF ROT. Y =	1.63
Z	90.68	91.23	1.41	STD. DEV. OF ROT. Z =	9.60

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RIGHT THIGH: REGRESSION EQUATIONS

RIGHT THIGH VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT		CONSTANT	R	SE EST*
VOLUME	=	35.19 +	45.30 -		4,083	.962	4.8%
X MOMENT	=	28,839 +	6,407 -		4,659,953	.953	9.6%
Y MOMENT	=	28,559 +	7,298 -		4,679,995	.957	9.2%
Z MOMENT	=	-1,587 +	4,537 -		72,496	.957	8.9%

RIGHT THIGH VOLUME FROM:

WEIGHT	MDTHIGH C	THIGH LGTH	CONSTANT	R	SE EST
55.96		+	347.73	.958	5.0%
35.47 +	226.30	-	8,131.49	.978	3.7%
24.80 +	241.40 +	94.37 -	11,499.63	.984	3.2%

RIGHT THIGH X MOMENT FROM:

STATURE	MDTHIGH C	THIGH LGTH	CONSTANT	R	SE EST
46,365		-	6,678,946	.939	10.7%
31,602 +	60,709	-	7,270,091	.969	7.8%
16,713 +	61,238 +	46,410 -	6,813,237	.981	6.3%

RIGHT THIGH Y MOMENT FROM:

STATURE	MDTHIGH C	THIGH LGTH	CONSTANT	R	SE EST
48,522		-	6,979,742	.940	10.5%
32,860 +	64,404	-	7,606,871	.972	7.4%
17,848 +	64,938 +	46,791 -	7,146,259	.982	6.0%

RIGHT THIGH Z MOMENT FROM:

WEIGHT	MDTHIGH C	UPPER THIGH CIRC	CONSTANT	R	SE EST
4,056		-	272,336	.955	8.8%
2,447 +	17,772	-	938,226	.979	6.2%
1,660 +	15,421 +	8,005 -	1,136,123	.984	5.5%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 27

LEFT THIGH

ANTHROPOMETRY

OF SEGMENT	RANGE	MEAN	S.D.
THIGH L	41.4- 53.1	46.55	3.42
UPPER THIGH CIRC	49.9- 65.7	57.82	3.97
MIDTHIGH CIRC	47.8- 60.1	52.90	3.01
MIDTHIGH DEPTH	15.9- 19.7	17.40	1.00
KNEE CIRC	33.5- 43.1	37.41	2.50
KNEE BR L	8.5- 11.1	9.57	.58
GLUT F DP	16.3- 22.7	19.38	1.44

LEFT THIGH VOLUME
RANGE	MEAN	S.D.
7,241 - 13,565	9,645	1,661
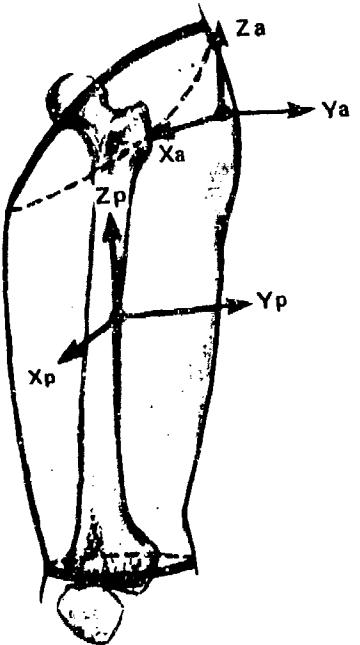
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN

	RANGE		MEAN	S.D.
X-AXIS	-.46	- 2.29	.71	.72
Y-AXIS	-8.00	- -5.26	-6.49	.63
Z-AXIS	-23.34	- -17.82	-20.12	1.53

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS

	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
L TROCHANTERION	.71	.72	-6.49	.63	-20.12	1.53
L LAT FEM CONDYL	.71	.72	-6.49	.63	23.89	1.63
L MED FEM CONDYL	.71	.72	4.80	.48	25.87	1.74
LEFT TIBIALE	-.48	1.24	2.99	.90	28.09	1.74
LEFT FIBULARE	-.14	1.04	-6.30	.77	26.76	1.89

THE PRINCIPAL MOMENTS OF INERTIA

	RANGE		MEAN	S.D.
X-AXIS	859,103 -	2,601,263	1,487,046	451,768
Y-AXIS	914,120 -	2,724,962	1,568,980	471,551
Z-AXIS	250,660 -	713,153	404,963	119,266

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES

	X	Y	Z	
X	10.43	79.59	90.53	STD. DEV. OF ROT. X = .93
Y	100.42	10.43	90.53	STD. DEV. OF ROT. Y = 1.75
Z	89.58	89.38	.75	STD. DEV. OF ROT. Z = 8.63

LEFT THIGH: REGRESSION EQUATIONS

LEFT THIGH VOLUME AND MOMENTS FROM STATURE AND WEIGHT

	STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME =	26.26 +	46.43 -	2,929	.950	5.6%
X MOMENT =	21,773 +	7,688 -	3,687,770	.935	11.2%
Y MOMENT =	21,577 +	8,474 -	3,704,865	.939	10.7%
Z MOMENT =	-1,134 +	4,249 -	117,848	.948	9.7%

LEFT THIGH VOLUME FROM:

WEIGHT	MOTHIGH C	STATURE		CONSTANT	R	SE EST
54.39			+	376.96	.948	5.6%
34.19 +	223.04		-	7,979.95	.968	4.5%
23.83 +	229.31 +	32.33 -		12,284.45	.971	4.3%

LEFT THIGH X MOMENT FROM:

WEIGHT	STATURE	MOTHIGH C		CONSTANT	R	SE EST
14,283			-	946,750	.915	12.5%
7,688 +	21,773		-	3,687,770	.935	11.2%
1,465 +	23,443 +	63,128 -		6,263,299	.957	9.3%

LEFT THIGH Y MOMENT FROM:

WEIGHT	MOTHIGH C	STATURE		CONSTANT	R	SE EST
15,009			-	988,567	.921	11.9%
9,532 +	60,483		-	3,254,750	.940	10.6%
2,066 +	65,002 +	23,297 -		6,356,847	.960	8.8%

LEFT THIGH Z MOMENT FROM:

WEIGHT	MOTHIGH C	UPPER THIGH CIRC		CONSTANT	R	SE EST
3,906			-	260,547	.947	9.6%
2,523 +	15,266		-	632,539	.966	7.9%
1,865 +	13,299 +	6,699 -		998,137	.970	7.5%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 28

TORSO

ANTHROPOMETRY
OF SEGMENT	RANGE	MEAN	S.D.
CHEST CIR	82.6-113.8	96.51	7.57
CHEST BR	28.4- 37.9	33.19	2.14
SUBSCAP SKINFOLD			
	7.0- 28.0	12.10	5.24
WAIST CIR	72.3- 99.7	85.70	7.88
BUTTOCK C	84.1-109.0	95.29	6.39
BUTT'K DP	20.6- 29.1	24.08	2.08
HIP BR	30.0- 40.8	34.62	2.33
TORSO L	64.9- 78.9	71.15	3.98

TORSO VOLUME
RANGE	MEAN	S.D.
26,236 - 53,062	38,115	7,346
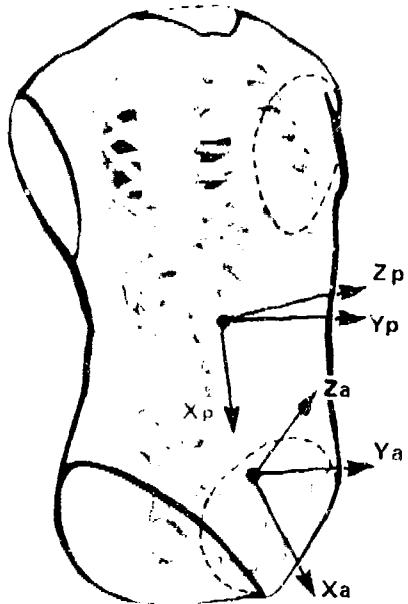
LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
	RANGE		MEAN	S.D.
X-AXIS	-6.78	- 2.49	-1.89	2.28
Y-AXIS	-1.73	- 1.72	.09	.81
Z-AXIS	18.98	- 25.61	21.41	1.57

LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS
	X-MEAN	X-S.D.	Y-MEAN	Y-S.D.	Z-MEAN	Z-S.D.
CERVICALE	-5.83	3.32	-.14	1.59	-32.46	2.48
LEFT ASIS	-1.89	2.28	-11.12	1.38	21.41	1.57
RIGHT ASIS	-1.89	2.28	11.31	1.31	21.41	1.57
SUPRASTERNALE	-13.97	2.53	.24	1.21	-21.17	2.14
SYMPHYSION	-1.89	2.28	.16	1.03	30.05	1.95

THE PRINCIPAL MOMENTS OF INERTIA
	RANGE		MEAN	S.D.
X-AXIS	8,045,156	- 23,787,262	14,386,049	4,322,462
Y-AXIS	7,433,074	- 21,894,753	13,003,769	3,958,326
Z-AXIS	2,252,535	- 7,194,668	4,375,485	1,413,519

PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
COSINE MATRIX EXPRESSED IN DEGREES
	X	Y	Z						
X	15.62	92.74	105.36	STD.	DEV.	OF ROT.	X =	2.39
Y	87.38	2.74	90.81	STD.	DEV.	OF ROT.	Y =	5.75
Z	74.62	89.92	15.38	STD.	DEV.	OF ROT.	Z =	2.30

TORSO: REGRESSION EQUATIONS

TORSO VOLUME AND MOMENTS FROM STATURE AND WEIGHT

		STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME	=	-114.73 +	282.09 +	10,411	.976	4.3%
X MOMENT	=	2,815 +	143,580 -	10,579,720	.967	8.0%
Y MOMENT	=	-830 +	131,633 -	9,279,222	.960	8.8%
Z MOMENT	=	-31,690 +	57,416 +	216,703	.983	6.2%

TORSO VOLUME FROM:

WEIGHT	SUBSCAP SKINFOLD	WAIST BR	CONSTANT	R	SE EST
247.34		-	4,031.67	.974	4.4%
220.55 +	265.73	-	2,681.51	.987	3.2%
173.70 +	195.32 +	640.81 -	13,840.00	.991	2.7%

TORSO X MOMENT FROM:

WEIGHT	TORSO LGTH	BUTT'K DP	CONSTANT	R	SE EST
144,433		-	10,225,320	.967	7.8%
83,641 +	470,625	-	33,327,869	.978	6.5%
52,834 +	521,549 +	412,663 -	41,644,194	.985	5.5%

TORSO Y MOMENT FROM:

WEIGHT	SUBSCAP SKINFOLD	TORSO LGTH	CONSTANT	R	SE EST
131,382		-	9,383,727	.960	8.6%
117,157 +	141,080	-	8,666,906	.973	7.3%
73,814 +	117,589 +	353,884 -	26,158,116	.980	6.4%

TORSO Z MOMENT FROM:

WEIGHT	SUBSCAP SKINFOLD	CHEST BR	CONSTANT	R	SE EST
47,818		-	3,772,674	.979	6.8%
43,478 +	43,040	-	3,553,988	.988	5.3%
35,609 +	40,008 +	128,070 -	6,428,388	.992	4.2%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

TABLE 29

TOTAL BODY

```
ANTHROPOMETRY
OF SEGMENT   RANGE      MEAN    S.D.
STATURE   162.3-194.3  177.49   9.63
WEIGHT    127.0-233.3  170.38  28.93
10 RIB BR 24.6- 33.6   29.85    2.33
10 RIB C  70.1- 95.7   82.15    7.16
SUBSCAP SKINFOLD
           7.0- 28.0   12.10    5.24
WAIST CIR 72.3- 99.7   85.70    7.88
SUPRAIL'C SKINFOLD
           6.0- 28.0   15.24    6.14
BUTTOCK C 84.1-109.0   95.29    6.39

        TOTAL BODY VOLUME
      RANGE           MEAN    S.D.
  59,484 -108,203    80,302  13,356
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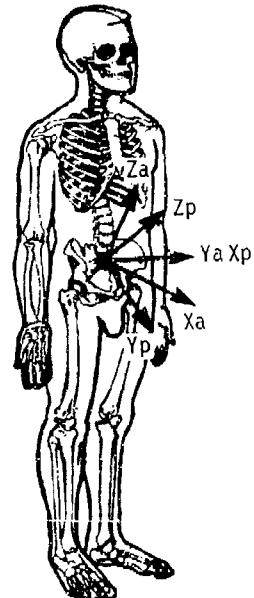


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LOCATION OF THE CENTER OF VOLUME FROM THE ANATOMICAL AXIS ORIGIN
              RANGE            MEAN      S.D.
X-AXIS  -11.42   -   -6.40    -8.69     1.38
Y-AXIS    -.90   -    .96      .04       .49
Z-AXIS   -2.30   -   8.16     3.02      1.87
```

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LOCATION OF THE CENTER OF VOLUME FROM ANATOMICAL LANDMARKS
                X-MEAN  X-S.D.  Y-MEAN  Y-S.D.  Z-MEAN  Z-S.D.
CERVICALE       -12.63   4.72    -.19    2.17   -50.85   3.77
LEFT ASIS        -8.69   1.38  -11.17    1.13     3.02   1.87
RIGHT ASIS       -8.69   1.38   11.27    1.22     3.02   1.87
SUPRASTERNALE   -20.76   3.93     .20    1.79   -39.56   3.58
SYMPHYSION       -8.69   1.38     .11     .62    11.66   1.97
```

```
THE PRINCIPAL MOMENTS OF INERTIA
            RANGE                        MEAN           S.D.
X-AXIS  88,439,435 - 203,043,411    135,395,337    34,042,243
Y-AXIS  83,399,023 - 138,134,006    126,368,113    31,577,709
Z-AXIS   8,116,878 -  24,100,314     14,432,630     4,235,469
```

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PRINCIPAL AXES OF INERTIA WITH RESPECT TO ANATOMICAL AXES
        COSINE MATRIX EXPRESSED IN DEGREES
        X       Y       Z
X   20.86   90.23   110.85    STD. DEV. OF ROT. X =  2.09
Y   89.76     .24    90.01    STD. DEV. OF ROT. Y =  5.32
Z   69.15   90.08    20.85    STD. DEV. OF ROT. Z =  1.79
```

TOTAL BODY: REGRESSION EQUATIONS

TOTAL BODY VOLUME AND MOMENTS FROM STATURE AND WEIGHT

	STATURE	WEIGHT	CONSTANT	R	SE EST*
VOLUME =	13.63 +	456.54 +	88	.998	1.1%
X MOMENT =	1,732,353 +	619,298 −	277,625,773	.993	3.0%
Y MOMENT =	1,750,747 +	526,985 −	274,187,835	.994	2.9%
Z MOMENT =	−40,033 +	155,980 −	5,049,460	.983	5.5%

TOTAL BODY VOLUME FROM:

WEIGHT	10 RIB BR	STATURE		CONSTANT	R	SE EST
460.67			+	1,803.68	.998	1.1%
430.84 +	420.32		−	5,638.59	.998	1.0%
409.52 +	483.85 +	55.49	−	13,748.96	.999	.9%

TOTAL BODY X MOMENT FROM:

WEIGHT	STATURE	10 RIB C		CONSTANT	R	SE EST
1,144,005			−	59,543,098	.972	6.0%
619,298 +	1,732,353		=	277,625,773	.993	3.0%
871,021 +	1,508,892 −	837,316	−	212,111,197	.996	2.3%

TOTAL BODY Y MOMENT FROM:

STATURE	WEIGHT	10 RIB C		CONSTANT	R	SE EST
3,192,171			−	440,242,306	.973	5.8%
1,750,747 +	526,985		−	274,187,835	.994	2.9%
1,560,581 +	741,201 −	712,555	−	218,434,961	.996	2.4%

TOTAL BODY Z MOMENT FROM:

WEIGHT	SUBSCAP SKINFOLD	STATURE		CONSTANT	R	SE EST
143,854			−	10,089,161	.983	5.6%
149,092 −	51,948		−	10,353,108	.984	5.4%
168,452 −	66,272 −	59,148	−	2,979,880	.985	5.3%

*SE EST EXPRESSED AS A PERCENTAGE OF THE MEAN

MOMENTS IN GM CM SQUARED
VOLUMES IN CUBIC CM
SKINFOLDS IN MM
WEIGHT IN POUNDS
ALL OTHER VALUES AND DISTANCES IN CM

Chapter IV

CONCLUSIONS

The results of this study demonstrate that mass distribution
properties can be estimated with a high degree of confidence from the
anthropometric measures of the body and that such estimates can be made
using various regression equations for both individuals and populations.

One method of judging the effectiveness of a regression equation is
to determine if it reduces the variability of the estimate to a significant
degree. For example, if it were necessary to estimate the volume of the
head of a particular individual without knowing any of that person's
dimensions, a "best estimate" would be the arithmetic mean of the sample
using the standard deviation to establish the confidence limits of the
estimate. Given dimensional information about the individual, the
regression value becomes a "best estimate" and the standard error of
estimate is used to establish the confidence limits. We can compare the
standard error of estimate of a given regression with the standard devia-
tion to determine the level of improvement in the prediction. In this
study, such a comparison indicates that the standard error of estimate
is generally one-third or less as large as the corresponding standard
deviation, an appreciable reduction in the confidence limits. Such compu-
tations for the head and neck segments show the least overall improvement
(on the order of 35 - 47 percent reduction) with the torso and total body
demonstrating the most improvement (on the order of 80 - 95 percent
reduction). The remainder of the segments show reduction in the standard
errors of the estimate over the standard deviation ranging from approxi-
mately 60 to 80 percent. There is no difference in these comparisons
between the segmental volumes and the principal moments of inertia.

In the selection of anthropometric variables for inclusion in the
regression equation, a measure of mass (weight, circumference or skinfold)
was generally the first dimension selected, a component of linearity the
second, with a segment breadth or depth selected third. The major excep-
tion to this pattern was for the stepwise regression variable selected for
the appendages when stature or a measure of segment length was selected
first for the I_{xx} and I_{yy} moment predictions. The variables for predicting
the segment volumes and I_{zz} principal moments were most frequently measures
of mass with measurements of linearity only being selected second or, more
commonly, third in the equation. As volume and moments are strongly related
to mass, it is not surprising that the anthropometric measures of weight
and circumference should appear most frequently in the predictive equations.

The alignment of the principal axes of inertia did not coincide closely
with the anatomical axes systems. This is not unexpected as the anatomical
axes systems were selected with less regard for the shape of the segment
than for the presence of bony, palpable landmarks which could be located
with some accuracy from subject to subject. However, for a large number of
segments, excellent alignment between the principal axes of inertia and the
segmental anatomical axes is achieved by a minor rotation of the anatomical
axis system about a single axis. This means that, for practical purposes,

the location of the principal axes could be envisioned by construction of the anatomical axes and the appropriate rotation empirically determined in this study. No anthropometric measurement or combination of body or segment measurements provide usable predictions of the orientation of the principal axes of inertia to the anatomical axis. The mean values as presented in Tables 5-29 (principal axes of inertia with respect to anatomical axes) are the best estimates of the orientation of the principal axes.

There is not, unfortunately, a major body of data available to compare with the results of this investigation. We can test the segment volume and moments of inertia results against the limited data obtained in the few studies in which cadavers were used and the total body volume and moments against the equally limited data from living subjects. Such comparisons are not as telling as we would like them to be since in the first instance we are comparing the data for living subjects with data for embalmed cadaveric segments and, in the second, comparing principal moments with those obtained for similar but undefined axes.

Table 30 compares results of this study with mean values for the moments of inertia for body segments determined in previous investigations. The values from Chandler (1975) and Becker (1972) are for principal moments about the center of mass and the values from Dempster (1955) were determined about an undefined X-Y axis through the center of gravity. In general, the values from this study are almost consistently larger than those obtained in previous investigations. These differences could, however, be primarily a result of comparing data obtained on cadavers with those obtained on the living.

TABLE 30

SEGMENTAL MOMENTS OF INERTIA (gmcm^2 x 10^3)

	Chandler et al.			Dempster	Becker			This Study		
	I_{xx}	I_{yy}	I_{zz}	I_{x-y}*	I_{xx}	I_{yy}	I_{zz}	I_{xx}	I_{yy}	I_{zz}
Head	174	164	203	–	199	221	134	204	233	150
Torso	16,194	10,876	3,785	18,400	–			14,386	13,004	4,375
Upper Arm Rt	135	133	20	142	–			128	136	26
Lt	152	138	23	139	–			123	130	25
Forearm Rt	67	65	9	56	–			86	87	13
Lt	65	63	9	55	–			82	84	11
Hand Rt	8	6	2	5	–			13	10	4
Lt	7	6	2	4	–			13	11	4
Thigh Rt	1,137	1,158	225	1,100	–			1,551	1,633	419
Lt	1,151	1,221	213	1,080	–			1,487	1,569	405
Calf Rt	391	393	29	430	–			570	578	66
Lt	395	390	29	416	–			581	590	66
Foot Rt	32	31	7	31	–			46	43	8
Lt	33	30	8	29	–			44	42	8
Total Body	133,970	118,897	17,125	–	–			135,395	126,368	14,433

* This axis is undefined except to say that it is perpendicular to the long axis and passes through the center of mass.

In the second comparison shown in Table 31, the total body principal moments from this study are compared with the results obtained by others for an aligned, but not necessarily principal, axis through the center of gravity. Again, the results of this study are of a larger magnitude than reported by others. These results could be a function of the somewhat taller and heavier subjects used in this study, or, they could be a result of our measuring the principal and largest, as opposed to a lesser, moment about an undefined axis.

TABLE 31

TOTAL BODY MOMENTS OF INERTIA ($gmcm^2 \times 10^3$)

	n	I_{xx} $\bar{x}$	SD	I_{yy} $\bar{x}$	SD	I_{zz} $\bar{x}$	SD
Santschi	66	130,035	21,823	116,467	20,240	12,777	2,488
Ignazi	11	123,827	20,319	115,145	19,916	11,191	2,922
This Study	31	135,395	34,042	126,368	31,578	14,433	4,385

A companion study of women has been initiated and data analysis is currently in progress. It is hoped that data from both these studies will furnish the impetus for further validation of this relatively uncomplicated approach to the determination of human mass distribution properties.

Appendix A

DEFINITION OF TERMS AND LANDMARKS

ABDOMINAL: pertaining to the abdomen, particularly the region below the rib cage and above the pelvis.

ACROMION: the bony process which forms the lateral extension of the scapular spine.

ACROMION LANDMARK: the most lateral point on the lateral edge of the acromial process of the scapula. A point on the tip of the shoulder.

ADAM'S APPLE LANDMARK: the anterior point in the mid-sagittal plane of the thyroid cartilage.

ANTERIOR: pertaining to the front of the body; as opposed to posterior.

ANTERIOR SUPERIOR ILIAC SPINE LANDMARK: the most prominent point on the anterior superior spine of the ilium.

AXILLA: the armpit.

BI: a prefix relating to each of two symmetrically paired points.

BICEPS (BRACHII M.): the large muscle on the anterior side of the upper arm.

BICEPS LANDMARK: the most superior point on the biceps muscle when the upper arm is held horizontal and the biceps is flexed.

CERVICALE LANDMARK: the superior tip of the spine of the 7th cervical vertebra.

CLAVICALE LANDMARK: the point on the most eminent prominence of the superior aspect of the medial end of each clavicle.

CLAVICLE: the long bone extending from the upper border of the sternum laterally and posteriorly to the acromion of the scapula; the collarbone.

DACTYLION: the tip of the middle finger.

DIGIT (I - V): a finger or toe, numbered sequentially from the thumb or big toe (digit I).

DISTAL: the end of a body segment furthest from the torso; the opposite of proximal.

DORSAL: pertaining to the back or the posterior surface.

EPICONDYLE: an eminence upon a bone above its rounded projection which is usually for articulation.

FEMORAL EPICONDYLE LANDMARKS: the lateral point on the lateral epicondyle and the medial point on the medial epicondyle of each femur.

FEMUR: the long bone of the thigh.

FIBULA: the smaller of the two long bones of the calf or lower leg.

FIBULAR LANDMARK: the superior point of the fibula.

FRANKFORT PLANE: the standard horizontal plane of orientation of the head, containing tragion and the lowest point of the orbit. This is closely approximated when the subject looks directly forward with his line of vision parallel with the floor.

GLABELLA LANDMARK: the most anterior point of the forehead between the brow ridges, in the mid-sagittal plane.

GLUTEAL FURROW: the furrow formed by the protrusion of the buttock beyond the back of the leg.

GLUTEAL FURROW LANDMARK: the most inferior point of the gluteal furrow.

GONIAL ANGLE: the obtuse angle at the back of the lower jaw formed by the intersection of the vertical and horizontal portions of the jaw.

GONION LANDMARK: the inferior posterior tip of the right and left gonial angles, the most prominent point on the angle of the jaw.

HUMERAL EPICONDYLE LANDMARKS: the lateral point on the lateral epicondyle and the medial point on the medial epicondyle of each humerus.

ILIAC CREST: the superior rim of the ilium or pelvic bone.

ILIOCRISTALE LANDMARK: the most superior point of the iliac crest in the mid-axillary line.

ILIUM: the upper one of three bones composing either lateral half of the pelvis.

INFERIOR: lower, nearer to the feet.

INFRAORBITALE: the lowest point on the inferior margin of the orbit or eye socket.

INFRAPATELLA LANDMARK: the inferior point on the patella while it is in the relaxed position.

INGUINAL LIGAMENT: the ligament which extends from the anterior superior iliac spine to the pubic tubercle and forms the groin crease.

LATERAL: lying away from the mid-sagittal line of the body; opposed to medial.

MALLEOLUS LANDMARK: the bony protrusion, either lateral or medial, of the ankle.

MASTOID: the bony eminence on the inferior posterior aspect of the temporal bone behind the ear.

MASTOID LANDMARK: the most inferior point of the mastoid process.

MEDIAL: lying near the mid-sagittal plane of the body; opposed to lateral.

METACARPALE: the joint or juncture of a bone of the palm (metacarpal) with the first bone (phalanx) of the finger. Numbered sequentially I (thumb) through V (little finger).

METACARPALE III LANDMARK: the distal palpable point on the metacarpal bone of the third digit on the posterior surface of the hand.

METACARPALE-PHALANGEAL LANDMARKS (II and V): the lateral prominent point on the lateral surface of the second metacarpal and the medial prominent point on the medial surface of the fifth metacarpal.

METATARSAL: a bone in the instep of the foot. Numbered sequentially I (big toe) through V (little toe).

METATARSAL-PHALANGEAL LANDMARKS (I and V): the medial point on the head of the metatarsus I and the lateral point on the head of metatarsus V.

MID-AXILLARY LINE: the vertical line which originates at the apex of the axilla.

MID-SAGITTAL PLANE: the vertical plane which divides the body into right and left halves.

NUCHALE LANDMARK: the lowest point in the mid-sagittal plane of the occiput that can be palpated among the nuchal muscles. This point is often visually obscured by hair.

OCCIPUT: the bone at the back of the skull; the region of the back of the head.

OLECRANON: the large bony process at the upper end of the ulna, one of the two long bones of the forearm.

OLECRANON LANDMARK: the posterior point on the olecranon.

OMPHALION: the mid-point of the umbilicus or navel.

PATELLA: the kneecap.

PHALANX: (plural, phalanges) a bone of the fingers or toes.

POSTERIOR: pertaining to the back of the body; opposed to anterior.

POSTERIOR CALCANEOUS LANDMARKS: the posterior point on each heel.

POSTERIOR SUPERIOR ILIAC SPINE LANDMARK: the point on the mid-spine made at the level of the posterior superior iliac spines.

PROXIMAL: the end of a body segment nearest the torso; opposed to distal.

RADIALE STYLOID LANDMARK: the point at the distal tip of the radius.

RADIALE LANDMARK: the highest point on the proximal head of the radius, near the mid-point of the elbow joint on the posterior side of the arm.

RADIUS: one of the two bones of the lower arm. This bone extends from the lateral side of the elbow to the wrist at the base of the thumb.

SCAPULA: the large flat triangular bone forming the back of the shoulder; the shoulder blade.

SCYE LANDMARKS: the point marking the upper end of the axillary fold, either right or left, anterior or posterior, which is the skin furrow formed by the juncture of the upper arm and torso.

SELLION LANDMARK: the greatest indentation of the nasal root depression in the mid-sagittal plane.

SPHYRION LANDMARK: the most distal point on the medial side of the tibia.

STERNUM: the breastbone.

STYLION: see ULNAR-STYLOID LANDMARK.

STYLOID PROCESS: a bony protuberance resembling a stylus. On the radius and ulna this occurs at the distal end of the bone.

SUB: a prefix denoting under or beneath.

SUPERIOR: higher, nearer to the head; as opposed to inferior.

SUPRA: a prefix denoting above or superior to.

SUPRASTERNALE LANDMARK: the lowest point in the notch in the upper edge of the breastbone.

SYMPHYSION LANDMARK: the lowest point on the superior border of the pubic symphysis, the anterior juncture of the pelvic bones.

TENTH RIB LANDMARKS: the inferior point on the inferior border of each tenth rib. The mid-spine landmark is at this level but marked on the mid-spine.

THELION: the mid-point of the nipple.

TIBIALE LANDMARK: the uppermost point on the medial superior border of the tibia.

TOE II LANDMARK: the anterior point of the second digit of each foot.

TRAGION LANDMARK: the point located at the notch just above the tragus of the ear. This point corresponds approximately to the upper edge of the ear hole.

TRAGUS: the small cartilaginous flap of flesh in front of the ear hole.

TRICEPS LANDMARK: with the right elbow flexed 90°, the level on the back of the upper arm halfway between acromion and the tip of the elbow.

TRICEPS M: the large muscle on the back of the upper arm.

TROCHANTER: a large prominence of a bone for the attachment of rotator muscles.

TROCHANTERION LANDMARK: the superior point on the greater trochanter of the femur.

ULNA: one of the two bones of the lower arm; this bone runs from the tip of the elbow to the wrist on the same side as the little finger.

ULNAR STYLOID LANDMARK: the most distal point on the ulna.

UMBILICUS: the navel.

VENTRAL: the front surface; opposed to dorsal.

VERTEX: the top of the head in the mid-sagittal plane when the head is held in the Frankfort plane.

ZYGOMATIC ARCH: the bony arch extending horizontally along the side of the head from the cheekbone (malar) nearly to the external ear.

MEASUREMENT DESCRIPTIONS*

Abdomen Segment Length (82): a dimension calculated by subtracting iliac crest height from tenth rib height.

Acromion Height (7): subject stands erect, feet together, with head oriented in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the acromion landmark.

Acromion-Radiale Length (20): with a beam caliper, measure the distance along the long axis of the upper arm between the acromion and radiale landmarks.

Ankle Breadth (34): with a sliding caliper, measure on the ankle the maximum distance between the medial and lateral malleoli.

Ankle Circumference (62): with a tape perpendicular to the long axis of the lower leg, measure the minimum circumference of the ankle.

Anterior-Superior Iliac Spine Height (13): subject stands erect, heels together, with head oriented in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the anterior superior iliac spine landmark.

Arch Circumference (63): subject stands with his weight equally distributed on both feet. With a tape perpendicular to the long axis of the foot and passing over the highest point in the arch, measure the circumference of the foot at the arch.

Axillary Arm Circumference (65): with a tape perpendicular to the long axis of the upper arm and passing just below the lowest point of the axilla, measure the circumference of the arm.

Axillary Arm Depth (37): subject stands erect, arms hanging relaxed at sides. With the beam caliper, measure the horizontal distance from the anterior to the posterior surface of the upper arm at the axilla level.

Ball of Foot Circumference (64): subject stands with weight equally distributed on both feet. With a tape passing over the metatarsal-phalangeal joints I and V, measure the circumference of the foot.

Biacromial Breadth (23): subject stands with upper arms hanging relaxed and forearms and hands extended forward horizontally. With a beam caliper, measure the horizontal distance between the right and left acromion landmarks.

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* All measurements were taken with the subjects' arms in a relaxed position at their sides, rather than in the anatomical position, and all unilateral measurements were taken on the right sides, unless otherwise specified.

Biceps Circumference Flexed, Right and Left (76/77): subject stands, upper arm raised so that its long axis is horizontal, elbow flexed 90°, biceps strongly contracted, and fist tightly clenched. With a tape perpendicular to the long axis of the upper arm, measure the circumference of the upper arm at the level of the biceps landmark.

Biceps Circumference Relaxed, Right and Left (66/67): subject stands erect, arms hanging relaxed at his sides. With a tape perpendicular to the long axis of the upper arm, measure the circumference of the upper arm at the level of the biceps landmark.

Biceps Depth (38): subject stands erect, arms hanging relaxed at his sides. With the sliding caliper, measure the horizontal distance from the anterior to the posterior surface of the upper arm at the level of the biceps landmark.

Biceps Skinfold (75): subject stands erect, arms hanging relaxed at his sides. With the Lange skinfold caliper, measure a thickness of a fold of skin and subcutaneous tissue parallel to the long axis of the right upper arm at the level of the biceps landmark.

Bispinous Breadth (27): subject stands erect, heels together. With a beam caliper, measure the distance between the right and left anterior superior iliac spine landmarks.

Bitrochanteric Breadth (Bone) (28): subject stands erect with his heels together. With a body caliper, measure the horizontal distance between the maximum protrusions of the right and left greater trochanters, exerting sufficient pressure to compress the tissue overlying the femurs.

Buttock Circumference (56): subject stands erect with his heels together. With a tape passing over the greatest posterior protrusion of the buttocks, and in a plane perpendicular to the long axis of the trunk, measure the circumference of the hips.

Buttock Depth (30): subject stands erect, heels together. With a beam caliper, measure the horizontal distance from the anterior to the posterior surface of the torso at the level of the maximum protrusion of the buttocks.

Calf Circumference, Right and Left (60/61): subject stands, weight evenly distributed on both feet. With a tape perpendicular to the long axis of the lower leg, measure the maximum circumference of each calf.

Calf Depth (33): subject stands erect, weight evenly distributed on both feet. With the beam caliper, measure the horizontal distance from the anterior to the posterior surface of the right calf at the level of maximum calf circumference.

Calf Segment Length (86): a dimension calculated by subtracting sphyrion height from tibiale height.

Cervicale Height (4): subject stands erect, heels together, with head in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the cervicale landmark.

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Chest Breadth (24): subject stands erect, with heels together, head in the Frankfort plane. With a beam caliper, measure the horizontal breadth of the chest at the level of right thelion. The measurement is made at the mid-point of quiet respiration.

Chest Circumference (53): subject stands erect, heels together, head in the Frankfort plane. With a tape passing over the nipples and perpendicular to the long axis of the trunk, measure the circumference of the chest. The measurement is made at the mid-point of quiet respiration.

Elbow Breadth, Right and Left (47/48): subject stands with elbows flexed about 110°. With a spreading caliper, measure the maximum breadth across the humeral epicondyles.

Elbow Circumference (68): subject stands with arms hanging relaxed at his sides. With a tape passing over the olecranon process of the ulna and into the crease of the elbow, measure the circumference of the elbow.

Fibular Height (18): subject stands erect with heels together, weight evenly distributed on both feet. With an anthropometer, measure the vertical distance from the floor to the fibular landmark.

Foot Breadth (36): subject stands with his weight equally distributed on both feet. With a slicing caliper, measure the breadth of the foot across the metatarsal-phalangeal joints I and V.

Foot Length (35): subject stands with his weight equally distributed on both feet. With a beam caliper, measure on the foot the distance from the posterior point of the heel to the tip of the longest toe.

Foot Segment Length: see FOOT LENGTH.

Forearm-Hand Segment Length (87): a dimension calculated by adding radiale-stylion length and hand length.

Gluteal Furrow Depth (31): subject stands erect with heels together, weight evenly distributed on both feet. With the beam caliper, measure the horizontal distance from the anterior to the posterior surface of the right thigh at the gluteal furrow landmark.

Gluteal Furrow Height (16): subject stands erect with heels together, weight evenly distributed on both feet. With an anthropometer, measure the vertical distance from the standing surface to the right gluteal furrow landmark.

Hand Breadth (42): subject positions hand with fingers together and extended, and thumb slightly abducted. With a sliding caliper, measure the breadth of the hand across the metacarpal-phalangeal joints II and V.

Hand Circumference (71): subject positions hand with the fingers together and extended and thumb slightly abducted. With a tape passing around the metacarpal-phalangeal joints II and V, measure the circumference of the hand.

Hand Length (41): subject positions hand with fingers together and extended. With a sliding caliper, measure the length of the hand from the distal wrist crease to the tip of digit III.

Hand Segment Length: see HAND LENGTH.

Head Breadth (46): with a spreading caliper, measure the maximum horizontal breadth of the head.

Head Circumference (51): with the tape passing above the brow ridges and parallel to the Frankfort plane, measure the maximum circumference of the head.

Head Length (45): with the spreading caliper, measure in the mid-sagittal plane the maximum length of the head between the glabella landmark and the occiput.

Head Segment Height (78): a dimension calculated by subtracting mastoid height from stature.

Hip Breadth (29): subject stands erect with his heels together. With a beam caliper, measure the horizontal distance across the greatest lateral protrusion of the hips.

Iliac Crest Height (11): subject stands erect with heels together, weight evenly distributed on both feet. With an anthropometer, measure the vertical distance from the floor to the iliocristale landmark.

Knee Breadth, Right and Left (49/50): subject sits, knees flexed about 90°. With a spreading caliper, measure the maximum breadth of the knee across the femoral epicondyles.

Knee Circumference (59): subject stands erect. With a tape perpendicular to the long axis of the leg and passing over the middle of the patella, measure the circumference of the knee. The subject is instructed not to lock his patella.

Lower Arm Segment Length: see RADIALE-STYLION LENGTH.

Mastoid Height (6): subject stands erect, heels together, head in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the mastoid landmark.

Metacarpale III-Dactylion Length (43): subject extends his fingers. With a sliding caliper parallel to the long axis of digit III, measure the distance from the metacarpale III landmark to the tip of the middle finger.

Mid-forearm Circumference (69): subject stands erect, arms hanging relaxed at his sides. With a tape perpendicular to the long axis of the forearm and midway between the radiale and the ulnar styloid landmarks, measure the circumference of the forearm.

Mid-forearm Breadth (39): subject stands erect, arms hanging relaxed at his sides. With the sliding caliper, measure the horizontal distance from the anterior to the posterior surface of the lower arm at a level midway between the radiale and the ulnar styloid landmarks.

Mid-thigh Circumference (58): subject stands erect, feet slightly apart, weight evenly distributed on both feet. With a tape perpendicular to the long axis of the leg and at the level midway between the trochanterion and tibiale landmarks, measure the circumference of the thigh.

Mid-thigh Depth (32): subject stands erect, heels together, weight evenly distributed on both feet. With the beam caliper, measure the horizontal distance from the anterior to the posterior surface of the thigh at the level midway between the trochanterion and tibiale landmarks.

Neck Breadth (22): subject stands with head in the Frankfort plane. With a beam caliper, measure the maximum horizontal breadth of the neck, superior to the trapezius muscles.

Neck Circumference (52): subject stands with head in the Frankfort plane. With a tape in a plane perpendicular to the long axis of the neck and passing over the laryngeal prominence (Adam's apple), measure the circumference of the neck.

Neck Segment Length (79): a dimension calculated by subtracting cervicale height from mastoid height.

Omphalion Height (12): subject stands erect, heels together, head in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to omphalion. The subject must not pull in his stomach.

Pelvic Segment Length (83): a dimension calculated by subtracting gluteal furrow height from the higher of the two iliocristale landmarks.

Radiale-Stylion Length (21): with a beam caliper parallel to the long axis of the forearm, measure the distance between the radiale and the ulnar-styloid landmarks.

Sitting Height (44): subject sits erect, head in the Frankfort plane. With the anthropometer, measure the vertical distance from the sitting surface to the top of the head.

Sphyrion Height (19): subject stands erect, feet slightly apart, weight evenly distributed on both feet. With the measuring block, measure the vertical distance from the standing surface to the sphyrion landmark.

Stature (3): subject stands erect, heels together, head in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the top of the head.

Subscapular Skinfold (73): subject stands. With a Lange skinfold caliper, measure the thickness of a fold of skin and subcutaneous tissue just below the inferior angle of the right scapula and parallel to the tension lines of the skin.

Suprailiac Skinfold (74): subject stands. With a Lange skinfold caliper, measure the thickness of a fold of skin and subcutaneous tissue in the right mid-axillary line at the level of the crest of the ilium and parallel to the border of the crest.

Suprasternale Height (8): subject stands erect, heels together, head in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the suprasternale landmark.

Symphysion Height (14): subject stands erect, heels together, with head in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the symphysion landmark.

Tenth Rib Circumference (54): subject stands erect, heels together, head in the Frankfort plane. With a tape passing over the torso at the level of the right tenth rib landmark and perpendicular to the long axis of the trunk, measure the circumference of the torso. The subject must not pull in his stomach.

Tenth Rib Height (10): subject stands erect, heels together, head in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the right tenth rib landmark.

Tenth Rib Torso Breadth (25): subject stands erect, heels together, head in the Frankfort plane. With the beam caliper, measure the horizontal breadth of the torso at the level of the right tenth rib landmark.

Thelion Height (9): subject stands erect, heels together, head in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the thelion.

Thigh Flap Segment Length (84): a dimension calculated by subtracting gluteal furrow height from trochanterion height.

Thigh Segment Length (85): a derived dimension calculated by subtracting tibiale height from trochanterion height.

Thorax Segment Length (81): a derived dimension calculated by subtracting tenth rib height from cervicale height.

Tibial Height (17): subject stands erect with heels together, weight evenly distributed on both feet. With an anthropometer, measure the vertical distance from the floor to the tibiale landmark.

Torso Segment Length (80): a derived dimension calculated by subtracting gluteal furrow height from cervicale height.

Tragion Height (5): subject stands erect, heels together, head in the Frankfort plane. With an anthropometer, measure the vertical distance from the floor to the tragion landmark.

Triceps Skinfold (72): subject stands. With a Lange skinfold caliper, measure the thickness of a fold of skin and subcutaneous tissue parallel to the long axis of the right upper arm at the level of the triceps landmark.

Trochanterion Height (15): subject stands erect with heels together. With an anthropometer, measure the vertical distance from the floor to the trochanterion landmark.

Upper Arm Segment Length: see ACROMION-RADIALE LENGTH.

Upper Thigh Circumference (57): subject stands with his legs apart. With a tape perpendicular to the long axis of the leg and passing just below the lowest point of the gluteal furrow, measure the circumference of the thigh.

Waist Breadth (26): subject stands, heels together. With a beam caliper, measure the horizontal breadth of the body at the level of omphalion.

Waist Circumference (55): subject stands erect with heels together. With a tape passing over omphalion and perpendicular to the long axis of the trunk, measure the circumference of the waist. The subject must not pull in his stomach.

Weight (2): body weighed with scales read to the nearest quarter pound.

Wrist Breadth (Bone) (40): with a spreading caliper, measure the maximum breadth of the forearm across the radial and the ulnar styloid processes using sufficient pressure to compress the flesh.

Wrist Circumference (70): with a tape perpendicular to the long axis of the forearm, measure the minimum circumference of the wrist proximal to the radial and ulnar styloid processes.

Appendix B

STATISTICAL TREATMENT OF PRINCIPAL AXES

The description of inertial properties of a rigid body requires the specification of an inertia tensor, a coordinate system origin and the orientation with respect to which the tensor is calculated. A coordinate system may be chosen in which the inertia tensor has all off-diagonal elements equal to zero. This coordinate system is called the principal axis system and the diagonal elements of the inertia tensor are the principal moments of inertia. The alignment of the principal axis system depends on the mass distribution properties of the segment and, in the case of sets of human body segments, can be expected to have a distribution because of the variability in body shape from subject to subject.

The inertial distribution properties of the human body are essential for the analysis of any dynamics involving rotational motion of body segments. While, in principle, the equations describing such dynamics can be written using general inertia tensors, such an approach is most awkward. The usual procedure is to use principal moments and specify segment dimensions in the principal axis system of that segment.

This approach requires the specification of only the three principal moments and not the total 3 x 3 inertia tensor. However, it does require the additional specification of the segment principal axes alignments.

In the comparison of data for all 31 subjects, the principal moments, which are scalar quantities, were regressed against directly measured body dimensions. The resulting regression equations provide segment principal moments as a function of these dimensions.

The determination of corresponding principal axis systems, which consists of the specification of triads of orthogonal vectors, poses a more difficult problem. While individual vectors can be averaged to find a mean and a distribution around the mean, it does not necessarily follow that averages formed using respective axes of orthogonal sets will lead to an average orthogonal coordinate system.

That this approach indeed does not work in general can be easily demonstrated by trying to find the average of two orthogonal coordinate systems. Consider two coordinate systems both orthogonal, denoted by subscripts 1 and 2 in Figure B-1. Since each system is orthogonal

$$\hat{X}_i \cdot \hat{Y}_i = \hat{X}_i \cdot \hat{Z}_i = \hat{Y}_i \cdot \hat{Z}_i = 0 \tag{1}$$

Consider the sums

$$\vec{U}_1 = \hat{X}_1 + \hat{X}_2, \ \vec{U}_2 = \hat{Y}_1 + \hat{Y}_2 \ \text{and} \ \vec{U}_3 = \hat{Z}_1 + \hat{Z}_2 \tag{2}$$
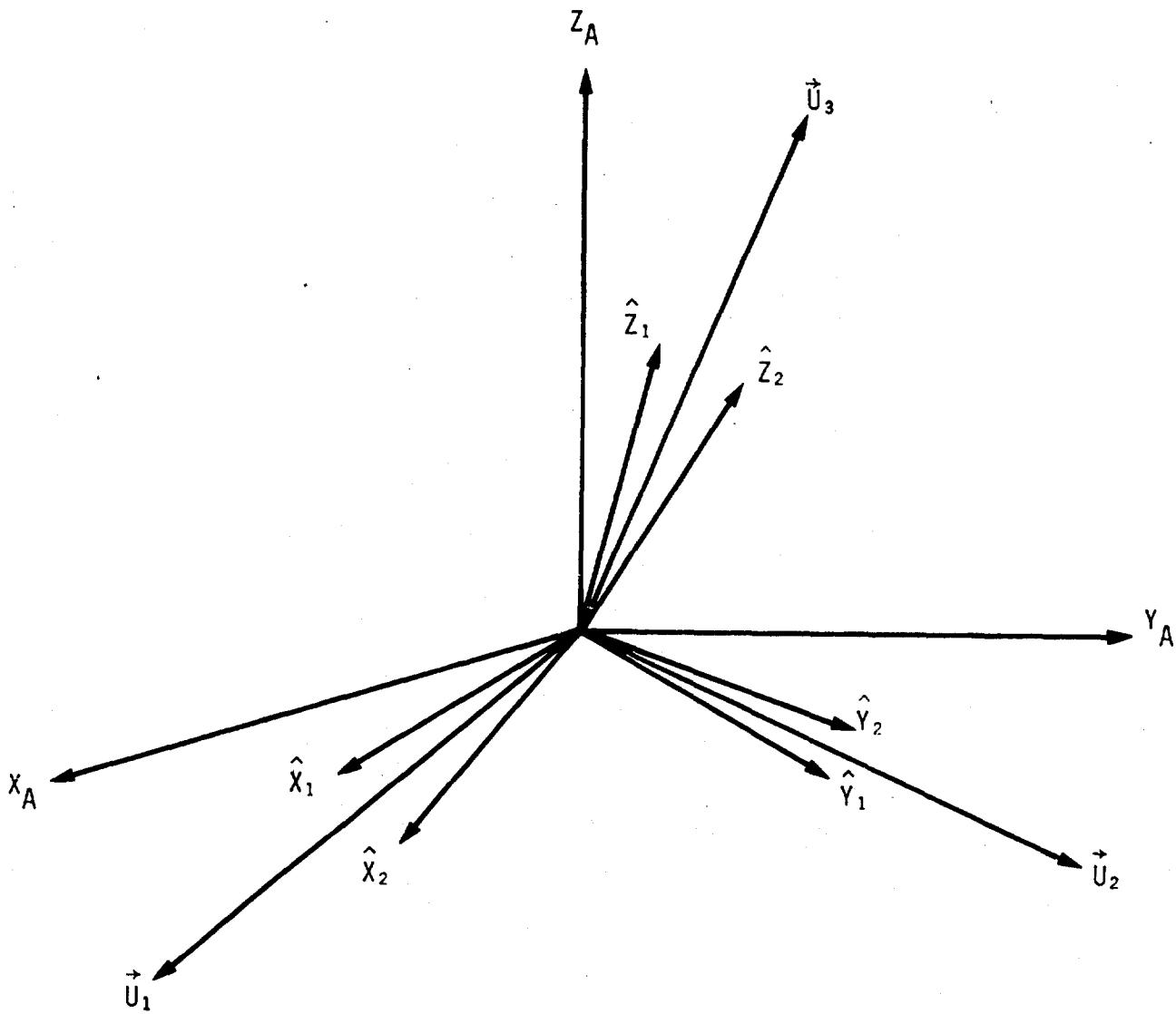
Figure B-1. An illustration of two orthogonal axis systems.

If $\vec{U}_1$, $\vec{U}_2$ and $\vec{U}_3$ formed an orthogonal set, then $\vec{U}_1 \cdot \vec{U}_2 = \vec{U}_1 \cdot \vec{U}_3 = \vec{U}_2 \cdot \vec{U}_3 = 0$,

however, consider the first term

$$\vec{U}_1 \cdot \vec{U}_2 = (\hat{X}_1 + \hat{X}_2) \cdot (\hat{Y}_1 + \hat{Y}_2) = \hat{X}_1 \cdot \hat{Y}_2 + \hat{X}_2 \cdot \hat{Y}_1 \tag{3}$$

where conditions (1) have been applied.

The system 2 vectors can be expressed in terms of the orthogonal system 1 unit vectors. Thus X_2 and Y_2 can be written in the form

$$\hat{X}_2 = \alpha_{x_2x_1}\hat{X}_1 + \alpha_{x_2y_1}\hat{Y}_1 + \alpha_{x_2z_1}\hat{Z}_1$$
$$\hat{Y}_2 = \alpha_{y_2x_1}\hat{X}_1 + \alpha_{y_2y_1}\hat{Y}_1 + \alpha_{y_2z_1}\hat{Z}_1 \tag{4}$$

where the α_{xy} is the cosine of the angle between the X and Y axes. Substituting these relations into equation (3) and using the properties from (1) we find

$$\vec{U}_1 \cdot \vec{U}_2 = \alpha_{x_2y_1} + \alpha_{y_2x_1} = \cos \angle X_2Y_1 + \cos \angle Y_2X_1 \tag{5}$$

Since, in general, this term will not be equal to zero, $\vec{U}_1$ and $\vec{U}_2$ are not in general orthogonal. If systems 1 and 2 are closely aligned, then the angles between X_2 and Y_1, and Y_2 and X_1 will be close to $\Pi/2$ and the cosine of these angles will be small, indicating that $\vec{U}_1$ and $\vec{U}_2$ are almost orthogonal.

The same analysis can be performed on $\vec{U}_1 \cdot \vec{U}_3$ and $\vec{U}_2 \cdot \vec{U}_3$ to show that these terms are also not generally equal to zero and therefore the summation of respective axes vectors does not lead to an orthogonal vector set. However, as indicated for $\vec{U}_1 \cdot \vec{U}_2$, if the summed axes are closely bunched, the resultant vectors are close to an orthogonal set. Since the final averaged axis system chosen had to be orthogonal, the following procedure was applied to generate an orthogonal system.

Taking N coordinate systems with respective axes vectors X_i, Y_i and Z_i, we formed the sums

$$\vec{U}_1' = \sum_{i=1}^{N} \hat{X}_i \quad , \quad \vec{U}_2' = \sum_{i=1}^{N} \hat{Y}_i \quad , \quad \vec{U}_3' = \sum_{i=1}^{N} \hat{Z}_i \tag{6}$$

By taking dot products among these vectors, as we did for N=2 above, we can show again that they do not equal zero and thus do not form an orthogonal set of vectors. However, if the summed unit vectors are closely aligned, then these products will be small and $\vec{U}_1$, $\vec{U}_2$ and $\vec{U}_3$ are close to an orthogonal set.

Since our intent is to find an average orthonormal principal axis system, an orthogonal set $\vec{U}_1$, $\vec{U}_2$ and $\vec{U}_3$ is first obtained by taking

$$\vec{U}_1 = \vec{U}_1'$$

$$\vec{U}_2 = \vec{U}_2' - (\vec{U}_1' \cdot \vec{U}_2')\vec{U}_1'$$

$$\vec{U}_3 = \vec{U}_1 \times \vec{U}_2 \tag{7}$$

A second and third set of these orthogonal vector sets were generated by permutation of the indices 1→2 and 2→3, respectively. This was done to remove any sequencing bias introduced in the orthogonalization process defined by equation (7). These vectors were then normalized to unit vectors and the respective axes vectors (three for each axis) summed as in equation (6). The orthogonalization procedure described above was again applied and the total procedure repeated until

$$\hat{U}_1 \cdot \hat{U}_2; \quad \hat{U}_1 \cdot \hat{U}_3; \quad \hat{U}_2 \cdot \hat{U}_3 < .0001 \tag{8}$$

In most cases this condition was satisfied by one pass through the ortho-normalization process with only a few cases requiring two passes.

The average principal axis system alignment with respect to the ana-tomical axis system can be expressed by a cosine matrix, $\underline{D}_{\bar{p}a}$, which relates the components of a vector in the principal system to those in the anatomical system by

$$\vec{R}_{\bar{p}} = \underline{D}_{\bar{p}a} \vec{R}_a \tag{9}$$

Also, each individual principal axis system can be related by $\underline{D}_{p_i\bar{p}}$ to the average principal system so that a vector in this system is related to the same vector in the average principal system by

$$\vec{R}_{p_i} = \underline{D}_{p_i\bar{p}} \vec{R}_{\bar{p}} \tag{10}$$

If we choose an axis vector for $\vec{R}_{p_i}$, for example $\hat{X}_{p_i}$, then

$$\hat{X}_{p_i} = \alpha_{xx}\hat{X}_{\bar{p}} + \alpha_{xy}\hat{Y}_{\bar{p}} + \alpha_{xz}\hat{Z}_{\bar{p}}$$

where α_{xx}, α_{xy} and α_{xz} are the projections of the unit vector $\hat{X}_{p_i}$ along the $\hat{X}_{\bar{p}}$, $\hat{Y}_{\bar{p}}$ and $\hat{Z}_{\bar{p}}$ axes, respectively. This is shown in Figure B-2.

To examine the distribution of the individual principal axes vectors about the average principal axes vectors, we take

$$\hat{X}_{P_i} = \alpha_{ixx}\hat{X}_{\bar{p}} + \alpha_{ixy}\hat{Y}_{\bar{p}} + \alpha_{ixz}\hat{Z}_{\bar{p}}$$
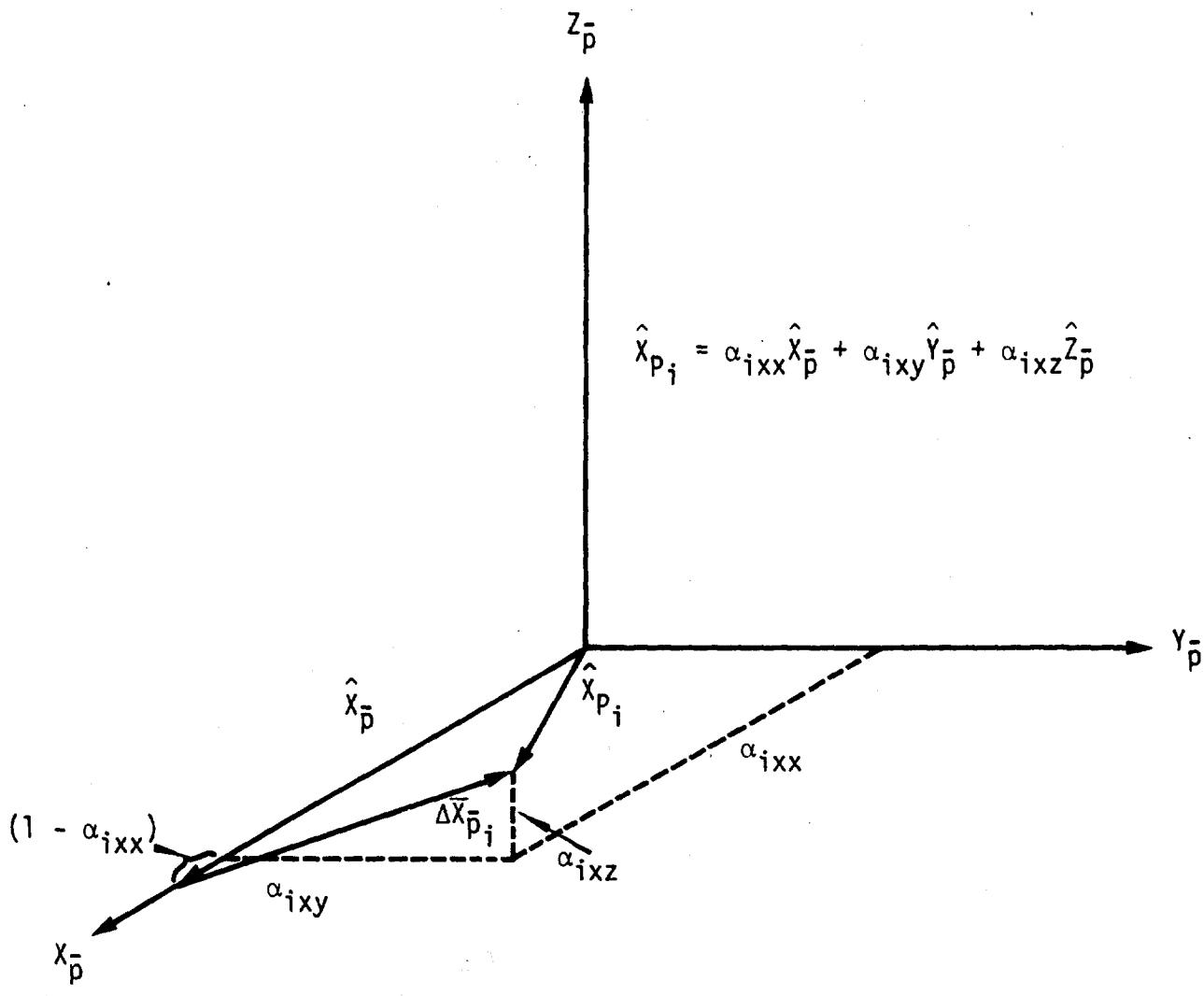
Figure B-2. A standard deviation unit vector $(\hat{X}_{pi})$.

$$\Delta \vec{X}_{\bar{p}_i} = \hat{X}_{p_i} - \hat{X}_{\bar{p}} = (\alpha_{ixx} - 1)\hat{X}_{\bar{p}} + \alpha_{ixy}\hat{Y}_{\bar{p}} + \alpha_{ixz}\hat{Z}_{\bar{p}}$$

$$\Delta \vec{Y}_{\bar{p}_i} = \hat{Y}_{p_i} - \hat{Y}_{\bar{p}} = \alpha_{iyx}\hat{X}_{\bar{p}} + (\alpha_{iyy} - 1)\hat{Y}_{\bar{p}} + \alpha_{iyz}\hat{Z}_{\bar{p}} \qquad (11)$$

$$\Delta \vec{Z}_{\bar{p}_i} = \hat{Z}_{p_i} - \hat{Z}_{\bar{p}} = \alpha_{izx}\hat{X}_{\bar{p}} + \alpha_{izy}\hat{Y}_{\bar{p}} + (\alpha_{izz} - 1)\hat{Z}_{\bar{p}}$$

which are expressed in the average principal axis system, and define

$$\sigma_{xx} = \frac{\sum\limits_{i=1}^{M} (\Delta X_{\bar{p}_i})_x^2}{M}, \quad \sigma_{yy} = \frac{\sum\limits_{i=1}^{M} (\Delta Y_{\bar{p}_i})_y^2}{M}, \quad \sigma_{zz} = \frac{\sum\limits_{i=1}^{M} (\Delta Z_{\bar{p}_i})_z^2}{M}$$

$$(12)$$

$$\sigma_{yx} = \frac{\sum\limits_{i=1}^{M} (\Delta X_{\bar{p}_i})_y^2}{M}, \quad \sigma_{xz} = \frac{\sum\limits_{i=1}^{M} (\Delta X_{\bar{p}_i})_z^2}{M}, \quad \sigma_{zy} = \frac{\sum\limits_{i=1}^{M} (\Delta Y_{\bar{p}_i})_z^2}{M}$$

and $\sigma_{xy} = \sigma_{yx}$, $\sigma_{xz} = \sigma_{zx}$, and $\sigma_{yz} = \sigma_{zy}$.

These are standard deviations defining the distribution of individual principal axes unit vectors about the respective average principal axes. They may be depicted graphically as shown in Figure B-3, where the σ_{xy}, σ_{xz} and σ_{yz} standard deviations can be viewed as defining ellipsoidal cones about each average principal axis.

Due to the orthogonality of the individual principal axis systems for every vector contributing a data point along one axis there are two other data points along the other two axes whose relative positions are determined by the orthogonality condition. This results, as also shown above, in

$$\sigma_{xy} = \sigma_{yx}; \; \sigma_{xz} = \sigma_{zx} \text{ and } \sigma_{yz} = \sigma_{zy}, \text{ as well as } \sigma_{xx} = \sigma_{yy} = \sigma_{zz} = \sigma.$$

The standard deviation cones can also be specified in terms of conical angles $\sigma_{rot\,x}$, $\sigma_{rot\,y}$ and $\sigma_{rot\,z}$, which are defined by

$$\sigma_{rot\,x} = \tan^{-1} \frac{\sigma_{zy}}{1-\sigma}$$

$$\sigma_{rot\,y} = \tan^{-1} \frac{\sigma_{xz}}{1-\sigma} \qquad (13)$$

$$\sigma_{rot\,z} = \tan^{-1} \frac{\sigma_{yx}}{1-\sigma}$$
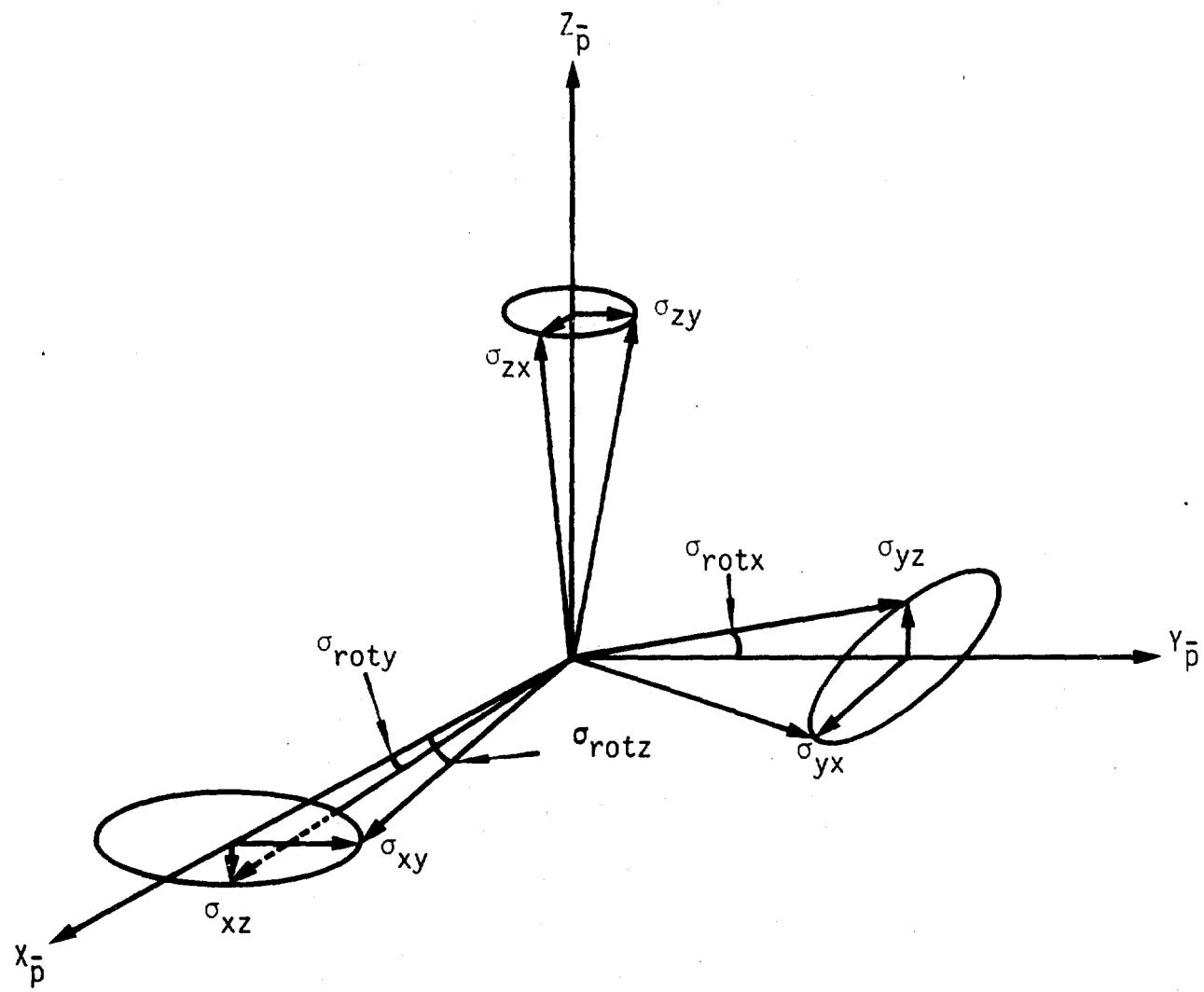
Figure B-3.   Ellipsoidal cones depicting the standard
             deviation of individual principal axes
             about average principal axes.

Appendix C

SOURCE DATA AVAILABLE TO USERS

The material presented in the main body of this report is statistical and was obtained from data gathered from 31 subjects. The basic data used in compiling these results consisted of both directly measured and stereo-photometrically derived body parameters. In the latter category a number of dimensions and other body characterizing quantities were calculated and compiled. Some of these quantities were directly compiled for the 31 subjects and the statistical results presented in the main body of the report. Others were intermediate results or considered not to be central to the overall study objectives.

In all, fourteen tables of data were generated and compiled for each subject. These tables contain the following data:

TABLE 1:

Body landmarks, as listed in Figure 5 in the main text of this report, specified in the Global Axes X_G, Y_G, Z_G system.

TABLE 2:

The calculated volume, percentage of total body volume and center of volume with respect to the Global Axes X_G, Y_G, Z_G of the 24 body segments and the total body.

TABLE 3:

The principal moments of inertia taken with respect to the center of volume of the body segments and the total body.

TABLE 4:

The direction cosines and the equivalent angles specifying the segment Principal Axes Xp, Yp, Zp orientation with respect to the Global Axes X_G, Y_G, Z_G for the 24 segments and the total body.

TABLE 5:

The origins of the segment Anatomical Axes X_A, Y_A, Z_A with respect to the Global Axes X_G, Y_G, Z_G for the 24 segments and the total body. The total body Anatomical Axes X_A, Y_A, Z_A system is taken to coincide with that defined for the pelvis.

TABLE 6:

    The direction cosines and the equivalent angles specifying the segment Anatomical Axes X_A, Y_A, Z_A orientation with respect to the Global Axes X_G, Y_G, Z_G for the 24 body segments and the total body. The total body Anatomical Axes X_A, Y_A, Z_A system is taken to coincide with that defined for the pelvis.

TABLE 7:

    The landmarks specified in Table 1 of this list are associated with a segment and the Anatomical Axes X_A, Y_A, Z_A origins are given in the segment Principal Axes Xp, Yp, Zp system for that respective segment the origin of which is at the segment volume center for the 24 body segments and the total body. Landmarks which define the Anatomical Axes X_A, Y_A, Z_A for each segment are separately listed with each segment.

TABLE 8:

    The centers of volume with respect to the total body Principal Axes Xp, Yp, Zp system for the 24 segments and the total body.

TABLE 9:

    The origins of the segment Anatomical Axes X_A, Y_A, Z_A systems with respect to the total body Principal Axes Xp, Yp, Zp system for the 24 segments and the total body.

TABLE 10:

    The landmarks specified in Table 1 of this list and associated with a segment and the centers of volume are given in the segment Anatomical Axes X_A, Y_A, Z_A system for each respective segment for the 24 body segments and the total body. Landmarks which define the Anatomical Axes X_A, Y_A, Z_A for each segment are separately listed for each segment.

TABLE 11:

    The centers of volume with respect to the total body Anatomical Axes X_A, Y_A, Z_A system for the 24 segments and the total body.

TABLE 12:

    The origins of the Anatomical Axes X_A, Y_A, Z_A with respect to the total body Anatomical Axes X_A, Y_A, Z_A for the 24 segments.

TABLE 13:

The direction cosines and the equivalent angles specifying
the segment Anatomical Axes X_A, Y_A, Z_A orientation with respect
to the segment Principal Axes Xp, Yp, Zp for the 24 body segments
and the total body.

TABLE 14:

The inertia tensors taken with respect to the segment volume
center and along the Global Axes X_G, Y_G, Z_G for the 24 body
segments and the total body.

These data are on magnetic tape at the Air Force Aerospace Medical
Research Laboratory and are available, upon request, to interested users.

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